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The ENGINEERS DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII No. 8 AUGUST, 1957

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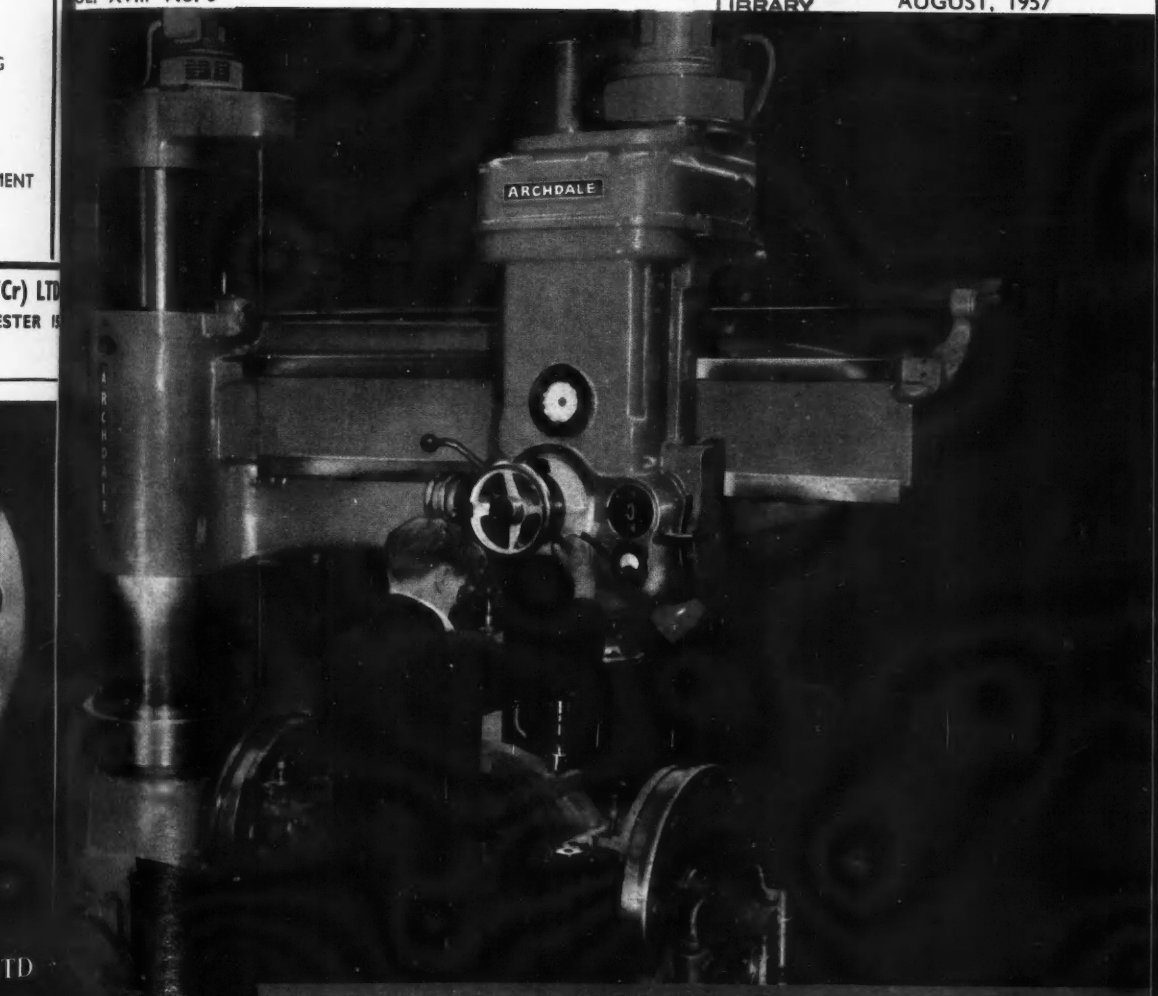

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CONTENTS

	Page
The Blue Pages	331
Coefficients of Friction of Flat Sliders	335
Tests on a Bearing with Three Wedge Films	340
The ONERA Process of Skin Annealing in a Gaseous Atmosphere	345
The Use of "Motocylinders" for Producing Reciprocating Motion	347
Pressure Dependence of the Electrical Breakdown Strength of Hydrocarbons	349
Carbon-Brush Friction and Chatter	351
Engineering, Marine, Welding, and Nuclear Energy Exhibition	355
British Industrial Developments	367
New Materials, Processes, and Equipment	371
News of the Month	373

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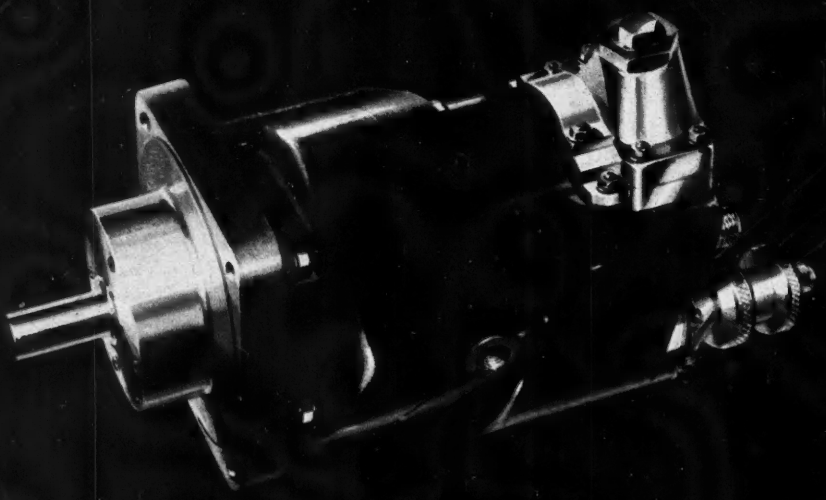

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *ULTRASONIC VIBRATION OF LIQUIDS*

In ultrasonic techniques, the difficulty arises that the variations of instantaneous pressure corresponding to sound waves transmitted in the atmosphere are of the order of several gm/cm², while, in order to produce sound waves of the same intensity in liquids, pressures of several kg/cm² must be used. A negligible portion of the sounds transmitted by the atmosphere can penetrate liquids, and hence the use of sirens for the ultrasonic treatment of liquids has not been successful. Various other methods have therefore been suggested and used. In a recently patented proposal, however, a compressed-air-operated siren-like structure, including a stator and a rotor, is used to produce a quick succession of alternating compressions and depressions in one or several chambers filled with air. The liquid in which the ultrasonic vibrations are to be produced is placed in a container, one wall of which consists of a flexible diaphragm which forms a partition between the liquid to be vibrated and the air or gas chamber in which the siren produces compression and depression cycles. Any other compressed gas can be used in the siren in place of air and, as an alternative, a device is proposed in which the compression and depression cycles are produced by intermittent explosions of a combustible mixture of a gas with air or oxygen.

● *BONDING CERAMIC TOOL TIPS WITH EPOXY RESINS*

Mechanical holders provide a satisfactory means of fastening ceramic tool tips to steel shanks for most cutting applications. However, in the case of precision boring operations or complicated tooling set-ups, bonded, rather than mechanically fastened, tips may be preferred. Unlike carbides, ceramics cannot be brazed unless the ceramic is first metallized, and this intermediate process is expensive. Moreover, the joints often fail in service, owing to brazing strains caused by the different coefficients of expansion of steel and ceramics. Unfortunately, most cements loosen or break down during cutting. To be successful, a material for bonding a ceramic tip to a steel shank must have sufficient strength to hold up under the stresses of cutting operations and should not melt or break down at the temperatures normally encountered in cutting. An additional requirement is that the bonding material should be capable of application at relatively low temperatures. Ceramic tools consist mostly of aluminium oxide, which is an insulating material with a coefficient of thermal conductivity about 50% that of carbide tooling materials. The cutting heat is therefore concentrated at or near the cutting edge of the tool. Furthermore, ceramic tools are most economically run at high speeds, and at such speeds a smaller percentage of the heat generated in cutting goes into the tool. It is reported that, in investigating the suitability of various cements, the use of epoxy resins was included, as, although the strength of these resins decreases rapidly with increasing temperature, it was considered that the ceramic would not transmit sufficient heat to the bond area to cause the resin to soften or decompose. Several successful applications of epoxy-bonded ceramic cutting tips are reported to have been made, the bond showing no indication of loosening. It has therefore been concluded that epoxy cements are excellent materials for bonding ceramic cutting tools to steel shanks.

● *DETERMINATION OF THE THERMAL CONDUCTIVITY OF METALS*

Various methods have been devised in the past for measuring the thermal conductivities of metals at room or higher temperatures. Fundamentally, these methods can be classified into two categories, i.e., steady and transient methods. Steady methods usually determine conductivities, while transient methods determine diffusivities. Steady methods often involve the measurement of heat quantity, resulting in a real problem in connection with the elimination of heat loss ; moreover, the time required for testing is rather long. In transient methods, changing temperatures, instead of heat quantity, are measured but, with the various methods of this type developed in recent years, the test specimens are mostly required in the form of long rods or wires, which are not always available in certain metals, and considerable time is required for carrying out measurements. It has therefore been a difficult task to maintain a constant temperature at the end of the rod or wire, or on one side of a plate for the duration of the test. It is now, however, reported in a recent paper that the problem has been solved

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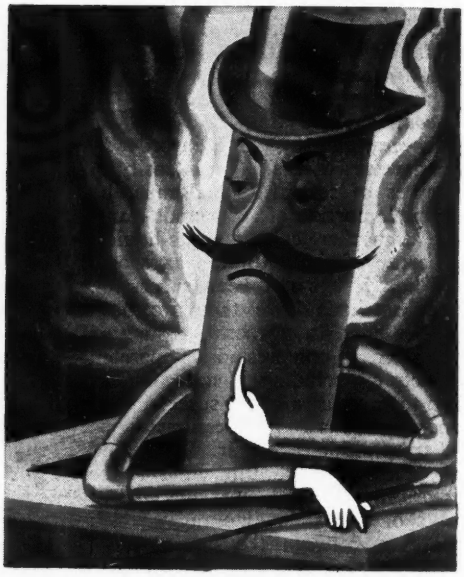
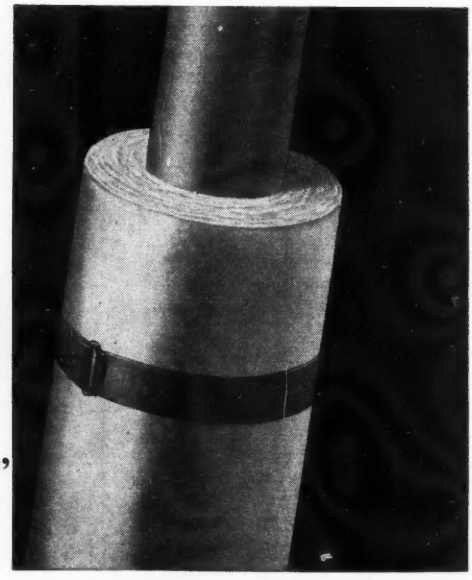


"I am a four-inch bore pipe. I work in a factory. It is my job to carry steam at 450°F. from generator to the plant. But I was a waster, a fuel waster, a *very* fuellish waster indeed!

I used to work naked as the day I was drawn. Of course I wasted heat — and therefore fuel — but who cared? Then one day, a bright spark from Fibreglass told the Manager that I was wasting nearly one ton of coal a year through each foot of my length.

I felt naked—and ashamed. Quickly they had me wrapped in a Fibreglass rigid section 1¾" thick. Now, this is saving 18½ cwts. of each ton I used to waste. My conscience is clear; but if pride is a sin, I'd better look out. Because I *am* proud of my slim figure, my neat nesting and my light-weight on hangers."



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by a method in which the two plates are suddenly brought together, so that the temperature at the contact plane remains constant during the testing period. In this method, the temperature on the flat side of a semi-infinite solid is suddenly raised to a certain value. Then, at two stations inside the solid, temperature variations with time are recorded by means of a thermocouple, a string galvanometer, and synchronized photographic equipment. Both thermal conductivity and specific heat can be determined in the same experiment. The time for measurement is only 30 sec, and the result is estimated to be accurate within 2% for certain metals. In the apparatus used, the experiments were performed within the temperature range of 20 to 80°C, but it is stated that, with special equipment, conductivity can be measured in any temperature range.

● *FOAM ALUMINIUM*

It is announced that a process of making foam aluminium has been devised by producing bubbles from the dispersion of metal hydrides in the liquid metal. At present, the material has been made only in experimental quantities, but it is considered that eventually it will be used in honeycomb sandwich structures, fuel cells, acoustic blocks, and floats, and that it may possibly become a substitute for timber in certain cases. The process can be so adjusted that the material can be made in densities ranging from 12 lb per cu ft (i.e., as light as balsa wood) to 40 lb per cu ft. Its cell form can be of the closed (floating) type or of the open (water-absorbing) type. The size of the individual bubbles can be reasonably controlled and may range from 1/64 in. to $\frac{1}{4}$ in. While the compressive and tensile strength of the material is naturally low, it is claimed to have considerable rigidity. Furthermore, being aluminium, it will not rust, rot, or be subject to attack by insects and rodents. Eventually, pieces of aluminium foam may be made in strips several feet wide and from 3 to 4 in thick. The problem of making the material in a continuous ribbon has not yet been solved, and more development work must be carried out to effect a closer control of density and shape. It is considered certain that one controlling factor in future developments will be the thickness of the material, which must, of course, be thin enough to allow heat to escape before the bubble form collapses. Temperature may also be a problem in fabricating this material, but it has been established that it can be sawed, nailed, cemented, screwed, soldered, and brazed at temperatures below its melting point. It is reported that attempts are being made to produce a similar material from magnesium, and it is considered possible that the same process may be applicable even to the production of foam steel.

● *TETRODE-TYPE TRANSISTORS*

It is well known that the frequency limitations of junction transistors constitute a deterrent to their wide application in the very-high-frequency range. However, several types of devices have shown possibilities for the improvement of the high-frequency performance of transistors. Thus, it is reported that tetrode types have been developed in production quantities specifically for applications up to 100 megacycles, while experimental units have produced maximum oscillation frequencies up to 1000 megacycles. A particular tetrode of this kind is made from germanium containing donor and acceptor impurities added in specific predetermined amounts to the single-crystal melt. The single crystal is processed into pellets of approximately 0·02 × 0·02 in. cross-section and 0·12 in. length, and, after cutting, the pellets are cleaned and prepared for melting back, the individual units being fed automatically into a melt-back furnace with a controlled atmosphere. The " doping " ratio existing within the initial pellet allows the impurities to segregate out under controlled conditions. When the melted portion of the pellet solidifies, a greater number of acceptor impurities separates out first, thus producing a *p*-type doped base. The width of the base may be varied to a considerable degree by using different doping ratios, impurities, and heating and cooling combinations to obtain the desired result. It is stated that the entire melting-back operation is carefully arranged to ensure a high yield of pellets with a base width under 0·0005 in., suitable for high-frequency use. Individual pellets are cleaned and evaluated prior to fabrication to determine their high-frequency potentialities.

● *CONTROLLED SURFACE HARDENING OF HEAT-TREATED PIECES*

When a metallic article of non-circular cross-section is heated and then hardened by subjecting it to uniform quenching, it becomes distorted and may even develop cracks. A particularly difficult problem is encountered with a severe quench, such as a water quench, which rapidly extracts heat from the metallic body. As a result, severe quenches have not been employed to any appreciable extent in the quenching of articles which do not have circular cross-sections, although such quenches produce a very hard metallurgical structure. The distortion produced by the uniform quenching of a metallic body of non-circular cross section is caused by the difference in the cooling rate of adjacent surface portions and, when the mass or cross-sectional area adjacent to a surface is comparatively large, a relatively large amount of heat will be contained in the material. Since a uniform quench extracts heat at the same rate

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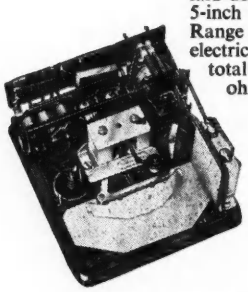

The instrument is self-contained, compact and portable, simple to operate, and is protected by an automatic cut-out against damage through inadvertent overload.

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from all parts of a steel piece to be quenched, the surface portions adjacent to the thick sections will cool less rapidly than the surface portions adjacent to the thin sections. Consequently, a thin layer of hard martensite is formed on the thick areas, which cool slowly, while the thin areas, which are rapidly cooled to a greater depth, have a relatively thick layer of martensite formed by the quench. The resulting uneven layer of martensite produces stresses which result in cracking and distortion. A recent invention envisages a method of quenching in which the hardness pattern produced by the quench is controlled by employing a sheet of quenching liquid with regulated heat-absorption properties. In this manner the rate of cooling of all portions of the body can be controlled and heat can be more rapidly abstracted from the thick areas which contain the greatest amount of heat. It is claimed that optimum results will be obtained by subjecting the entire surface of the piece to a scanning sheet of quenching liquid and effecting relative movement between the piece and the liquid.

● *CATHODIC ETCHING OF METALS*

It is well known that the cathodic sputtering technique, normally used for the deposition of thin metallic films, can be used for etching the surface of the cathode by exposing the grain boundaries and crystalline structure of the metal through bombardment of the surface by positively charged gas ions. It is also known that the sputtering rate can be increased by using a magnetic field in such a direction relative to the electric field as to permit a lowering of the working pressure of the gas in which the glow discharge takes place. Thus, a discharge operating at a given voltage and current density will, if a magnetic field is applied, continue to take place with the same electrical characteristics at a greatly reduced pressure. The exact mechanism by which an etch pattern, i.e., the exposure of grain boundaries or microscopic crystalline material at the previously polished surface of a sample, is produced by cathodic sputtering is not known with certainty. It may possibly be produced by variations in the sputtering rates of the cathode material over the crystalline surface, thus causing selective removal of the metal. Alternatively, it may be due to the atoms on the cathode surface obtaining appreciable atomic mobility under ion bombardment, permitting migration of the atoms in preferred positions over the cathode surface. A recent invention envisages the etching of the surface of a metallic body by making the body the cathode in a cathodic sputtering apparatus and employing a magnetic field with its lines of force extending towards the surface to be etched. In this way the working pressure of the gas in which the glow discharge takes place can be lowered. Conveniently, the lines of force of the magnetic field are normal to the surface to be etched and, in order to maintain symmetry of the glow discharge, an auxiliary cathode may be provided, the magnetic field also being normal to its surface. The gas-pressure range in cathodic etching with normal gas discharge systems is about 0·01 to 1 mm Hg, whereas, with the new system, the etching pressure can be lowered to about 1 micron Hg. At such low pressures, liberated atoms suffer few collisions in traversing the interspace between the chamber wall and cathode, so that the probability of their returning to the cathode is greatly reduced.

● *ACCURATE DIRECT MEASUREMENT OF TYRE OPERATING TEMPERATURES*

The operating temperatures of rubber tyres are of interest to manufacturers, as high temperatures are caused, at least in part, by power loss and affect the service life of tyres and hence the choice of materials used. Several methods have been used to determine these temperatures but, in general, they have been difficult to carry out or have been of questionable accuracy. The most accurate procedure for determining tyre operating temperatures involves computation from observed pressure and volume changes, but this method requires the use of a high-precision gauge and, because complex correction determinations are essential, is very time-consuming. Less complicated methods, based on the use of thermocouples, have also been used. In one of these, the thermocouple is vulcanized in the tyre tread, but this method has been found unsatisfactory because the thermocouple often breaks when the tyre is flexed. In another method, the thermocouple is inserted into the tread after the tyre has stopped rotating, but the results obtained with this method are not sufficiently accurate, as it has been found that, when a tyre is stopped abruptly, the temperature distribution shifts rapidly in a complicated manner. Now, however, it is reported that a precise, direct method, also using a thermocouple, has been developed for determining tyre operating temperatures, in which a copper-constantan thermocouple is inserted through the tyre valve. When the tyre is rotated under load, the thermocouple gives an accurate measurement of the average temperature of the air in the tyre. A series of tests, involving precise determination of temperatures in different parts of a tyre at various speeds, has been made to evaluate the accuracy of this method, and it has been found that the mean of calculated and thermocouple-determined temperatures for a number of different speed conditions agrees to well within 1°F.

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● *HERMETICALLY SEALED ALKALINE ELECTRIC STORAGE CELLS*

A recent patent is concerned with the improvement of a hermetically sealed electric storage cell of the alkaline type in which the gases developed in charging, or at least an essential portion of these gases, are reunited by reaction with the active material of the electrodes. Such storage cells can be sealed in any operating conditions, including the charging period. In the type of hermetically sealed alkaline cell proposed, the gases developed during the charging operation are absorbed by the active material of the electrodes of opposite polarity, the distance between these electrodes not exceeding 1 mm, and the intervening space being filled with a plastic mass comprising an electrically non-conductive powder which is wetted by and is resistant to the electrolyte. This powder may take the form of aluminium oxide or of a plastic material such as polyvinyl chloride, polystyrene, polyethylene, perlon, or nylon. The distance between the electrodes must be fixed independently of the plastic mass, and this may be effected by means of a solid insulation of strips of plastic or of corrugated plastic foil between the electrode plates. If desired, the powder mixture may contain a number of coarser grains, which serve as distance members. A small amount of lithium may be added to the positive electrode, to prevent its becoming poisoned by the substances present in the cell. It is claimed that practical tests on cells of this type have given excellent results, permitting rapid charging and discharging with strong currents, without exceeding at any time an internal gas pressure in the cell of 1 kg/cm^2.

● *EDDY-CURRENT LOSSES IN STEEL PLATES*

The problem of evaluating power loss is always present in any field of electrical engineering. In many instances the current distribution in conducting materials can be evaluated and the corresponding loss determined, but there remain a number of cases in which the physical geometry and field configurations are such that exact analysis is not possible, and loss evaluations for such cases must be based on experience expressed in empirical form, or on an analytical treatment modified to agree with experimental data. A typical case in point is the presence of current-carrying conductors near conducting surfaces, inducing eddy-current flow in the conducting surfaces and causing resistive and reactive losses. In the case of heavy currents, such losses appear in busbar installations, rotating equipment, transformers, and other electrical equipment. In large power transformers, in which the low-voltage connections may carry 6000 A r.m.s. or higher, the resulting field intensity is 220 oersteds or more at a distance of 3 in. A recent research report presents data for two conditions, i.e., a single lead parallel to a conducting magnetically permeable surface of typical steel transformer-tank plate material, and a single lead parallel to the same surface covered with aluminium plate of $\frac{1}{4}$ in. thickness. A test fixture is described which makes it possible to obtain data permitting the establishment of a correlation between current, conductor-to-plate spacing, and power loss, and the report shows that power loss is not a function of the square of the current when considering steel alone, but a function of current to a power of less than two, with power a function of conductor-to-plate spacing.

● *DIRECT ELECTRICAL RESISTANCE HEATING OF BILLETS*

A recent patent describes an improved process for the direct electrical resistance heating of steel billets and semi-finished steel products to rolling temperature. To carry out resistance heating successfully, the maintenance of good electrical contact is of the greatest importance, and this applies in particular to cases where large electric currents must be applied. Under such conditions local overheating of the contact points and of the adjacent zones of the steel billet may occur, so that the contact pressure produces distortion of the material. Also, the metallic structure of the heated material may be affected, and in extreme cases a part of the steel may be melted away. According to the invention, these shortcomings can be avoided by applying water to the ends of the billet while it is being heated, the cooling effect produced by the water being carefully controlled. In carrying out the process, water is continuously or intermittently applied to the points of contact between the ends of the billet and the points of contact after heating has started. The supply of water may be continuous throughout the heating period, or only for part of it. The extent and rate of cooling are controlled in accordance with the extent and rate of heating of the rest of the billet. This control can be carried out by automatic switches, and the application of the water can be effected by means of a nozzle located within the electrical contact itself, the nozzle spraying the water against the end of the billet. At the same time, the side faces of the billet not engaged by the electrical contacts are cooled by separate water sprays. Spray cooling of the side faces is, however, discontinued after a short time, and only the water spray from the nozzle inside the contact is maintained. Steam may be used as the cooling medium in place of water. Alternatively, any other suitable liquid may be used, provided that it is not injurious to the material to be heated.

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VOL. XVIII No. 8 AUGUST, 1957

Coefficients of Friction of Flat Sliders

By E. J. WEITER and A. O. SCHMIDT. (From *ASME Paper* No. 57-SA-100, presented at the ASME Semi-Annual Meeting, San Francisco, Cal., June 1957, 20 pages, 14 illustrations.)

WITH the development of automatic machine tools and new material applications—particularly to sliding components—additional and more accurate information on the frictional behaviour of flat sliding surfaces is required. Since interrupted motion is involved, the friction forces (which must be overcome in sliding) have a range of values under conditions of kinetic friction, as well as under those of static friction. Consequently, all the frictional characteristics of the sliding surfaces should be known.

The object of the investigation* described in this paper was to establish coefficients of static friction as well as the "break-away" and kinetic behaviour of selected material combinations. The values obtained in the tests here reported compare favourably with the forces and response observed in the testing of the positioning mechanisms on machine tools. This parallelism between experiment and performance can be attributed to the flat rectangular contact areas utilized in the friction apparatus.[1]

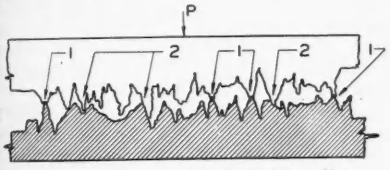

Fig. 1. Interface formed by two surface profiles.
(1) Asperity contact where welding can occur. (2) Interlocking.

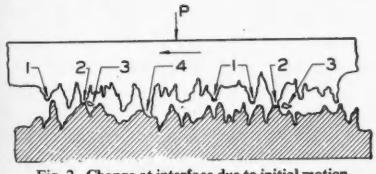

Fig. 2. Change at interface due to initial motion.
(1) Sheared weld. (2) New weld. (3) Loose wear fragment due to interlocks. (4) Ploughing.

Actual profiles of machined flat surfaces show that they are composed of large numbers of peaks (asperities) and valleys. The asperities vary in size, shape, number, and location, depending on the physical properties of the material and the method of finishing used. As shown in Figs. 1 and 2, it is evident that there is no similarity between the asperities on a given surface. A brief review of the generally accepted mechanism of friction indicates the importance of the asperity. The friction force, either static or kinetic, is the summation of the force necessary to shear the welded contact areas, the force required to plough the asperity of the hard material through the soft material, and the force needed to overcome interlocking of asperities. This can best be seen in Fig. 1, which shows actual surface profiles. Where direct contact of asperities is made, there is a probability of welding, at least in part, at this contact. Interlocking occurs when an asperity of one material is located in a valley of the material. When initial motion is produced, as shown in Fig. 2, the welds formed must be sheared, and the interlocked asperities must either be sheared or must plough through the softer material. Thus, it can be seen that the asperity plays a major role in the generation of the friction force.

When the sliding surface consists of a flat surface, the random location and geometry of the asperity become important. Many authors, including Bowden and Tabor[2], have shown the relationship between friction and the hardness of the materials. This relationship is valid, since the hardness is a measure of the capacity of the bulk material to withstand shearing. Also, the true contact area is a function of normal load and hardness when two flat surfaces are brought into contact. The number of contact areas is dependent on the actual surface profiles, and these areas are random in location. Investigating the contact area, Archard[3] correlated the number and size of the contact areas with the flow hardness of the materials.

In agreement with Archard[3], Holm[4] in his investigation of the resistance of electrical contact proved that the contact area is proportional to the load. Holm states that the asperities in initial contact must deform elastically and plastically until contact area is sufficient to carry the load. These analyses are based on the bulk properties of the materials under steady-state conditions and are applicable when analysis is confined to a single asperity. However, owing to the random location and geometry of the asperities composing the interface in flat surface sliding, the load-carrying asperities may be adjacent, especially when waviness is present on one of the surfaces. When load-carrying asperities are confined (Fig. 3), resistance to elastic and plastic deformation will differ from the bulk values.

Furthermore, random location of asperities has an effect on the frictional characteristics of lubricated flat sliding surfaces. The tendency is for the lubricant to be extruded from the interface of the flat surfaces as the normal load is applied, this extrusion being a function of the geometry of the available flow paths. Since these

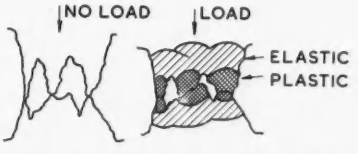

Fig. 3. Adjacent load-carrying asperities with confined deformation.

* Sponsored by the Kearney & Trecker Corporation and conducted in the Mechanical Engineering Laboratories of Marquette University, U.S.A.

flow paths are formed by the asperities, the extrusion of the lubricant may vary from unrestricted flow to complete entrapment.

The use of flat surfaces in the friction analysis includes the variables of confined deformation and lubricant extrusion introduced by the random location and geometric dissimilarity of the asperities.

Coefficients of static friction are generally given for steady-state conditions, implying that these coefficients are independent of time. However, the time the contacting surfaces are at rest prior to sliding produces changes at the interface which will affect the coefficient of static friction. Holm[4] points out that the plastic deformation of the asperity varies with the length of time the contacts are under load. In an investigation with silver under a load of 77·2 lb and a temperature of 65°F, the contact resistance varied from 17×10^{-6} ohms at initial contact (zero time) to $15{\cdot}84 \times 10^{-6}$ ohms after 5 hr. The significance of the decreased electrical resistance with time is that, through the process of atomic migration over a period of time, the resistance to plastic deformation is decreased and the asperity contact area is increased. Since plastic deformation in the form of creep appears to take place in all materials, varying only in degree, it can be concluded that static friction increases within limits, with respect to the time that the contact area has been at rest under load prior to break-away. This increase in friction would be due to the enlargement of area, both in size and number of asperity junctions, as well as to the accompanying increase in interlocking resulting from a closer mating of the materials.

At the instant that two flat sliding surfaces are brought to rest, time can be considered as zero. At zero time, the asperities are subjected to stresses in excess of those necessary to initiate plastic deformation. The magnitude of stress in the contacting asperities can be derived from work on contact area, such as the experiments of Bowden and Tabor with two finely ground and lapped steel surfaces having an apparent area of 3·25 sq in. They found that, with a normal load of approximately 11 lb, the actual contact area was 0·250% of the apparent area and, with a normal load of approximately 4·4 lb, the real contact area was only 0·001% of the apparent area. Although this work is assumed to have been done after the initial deformation had become stabilized, it shows that the magnitude of the stress in the contacting asperities must be extremely high when initial contact is made.

The asperity is therefore subjected to high stresses initially and to lower stresses after initial deformation has taken place. This introduces a time rate of stress loading. Recently, as a result of basic research in the area of microcrystalline behaviour, the validity of classifying a substance as ductile or brittle is open to question. Zastin[5] suggests that the determination of materials as ductile or brittle should be based on the ratio of the cohesive stress to the shear stress present in the stressed material, this ratio being determined by the rate of loading and the stress pattern. Consequently, brittleness and ductility are not inherent properties of a material. Since the asperities are subjected to extremely high initial stress, it appears that the physical properties of the material differ from its bulk, steady-state properties.

Although steady-state static friction is related to Brinell hardness, it should also be considered to vary with the time at rest. When the time at rest is less than 2 min, the authors' tests indicate that the effect of confined asperity deformation and the time rate of stress application becomes a factor. When the time at rest is extended, the increase in static friction due to atomic migration should be included. Existence at the interface of a foreign film, such as a lubricant, introduces another time-dependent variable in static friction, i.e., film extrusion.

When two flat surfaces are brought to rest, the thickness of the lubricant film is that which corresponds to the relative velocity of sliding. It can then be assumed that the film will be at its maximum thickness at zero time. When two flat surfaces remain at rest under load, the lubricant is extruded from the interface and the surfaces approach each other. The extrusion of the lubricant is dependent on the resistance of the available flow paths, the pressure produced by the load, and the properties of the lubricant, chiefly its viscosity. Since the flow is a function of time, it can be concluded that the effect of the lubricant in reducing the coefficient of static friction will vary with respect to the time that the surfaces have been at rest prior to motion. When the lubricant is extruded, the static friction will be similar to the dry condition, in which the time rate and pattern of stress, as well as atomic migration, are significant.

Description of Friction Apparatus

As shown in Fig. 4, the friction apparatus used in this investigation consists of a flat-surfaced slide (2), 4 in. wide by 30 in. long, pivoted at one end, with the other end capable of being elevated by a pneumatic cylinder (7). The angle θ which the inclined flat surface forms with the horizontal plane is read on a calibrated quadrant (1). The relationship of angle θ to the coefficient of friction μ is generally expressed as $\mu = \tan \theta$. The contacting areas of the slider (3) are two 0·250 × 2 in. rectangular flat surfaces which constitute an apparent contact area of 1 sq in. The slider is fitted into a saddle, from which a free-swinging rod is suspended, and contact loading is accomplished by addition of dead weights (8) to the rod.

A high-resistance nichrome wire (6), suspended from insulated fittings (4) at the ends of the slide, forms the variable leg of a Wheatstone bridge. A carbon contactor (5), attached to the slider, yields a linear relationship between resistance and position. The output from the bridge circuit is fed to a d.c. amplifier (9) and in turn to a channel of a direct-writing oscillograph (10).

Materials Tested and Procedure

The slide materials used included hardened and ground steel; ground cast iron; and hand-scraped cast iron. The first two materials were finished by standard grinding to a roughness of about 20 microinches r.m.s.

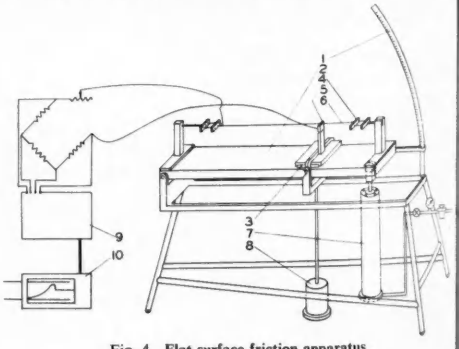

Fig. 4. Flat-surface friction apparatus.

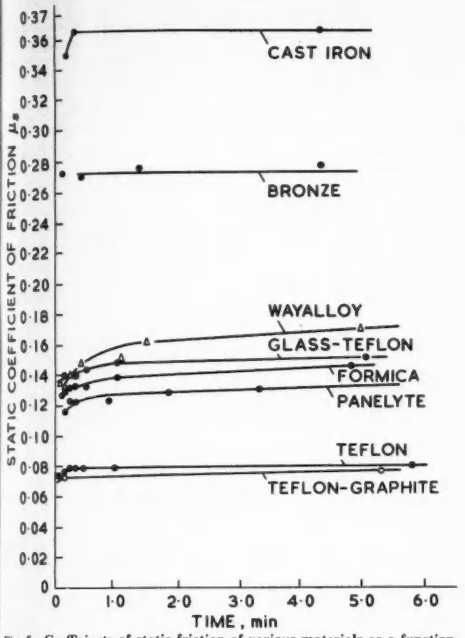

Fig. 5. **Coefficients of static friction of various materials as a function of time at rest under load on a ground cast-iron slide, under dry conditions and a 50-psi load.**

The hand-scraped cast iron had about 20 contact points per sq in., in accordance with generally accepted methods used in the machine-tool industry.

Slider materials comprised a number of plastics and metals, i.e., Formica; Wayalloy "A" (plastic with a wood filler); bearing bronze (aluminium bronze); ground cast iron (3·0 C, 1·8 Si, 0·9 Ni, 0·7 Mn); Panelyte; glass-filled Teflon; Teflon; and graphite-filled Teflon.

The Formica and Panelyte had been in storage for several years. Each of the slider materials was finished by grinding to approximate the finish on the slide, i.e., about 20 microinches r.m.s. No heat was applied to the plastic materials in attaching them to the slider mount, as this would have influenced the wear and sliding properties. When testing plastic material, with and without a heat treatment as used in machine-tool slides, Opitz and Saljé[6] obtained different values for the coefficient of friction under dynamic conditions.

The preparation of the metal slide and sliders consisted of washing the contact surfaces with carbon tetrachloride. Plastic sliders were washed in a solution of a standard detergent and water. In all lubricated tests, an oil, recommended for use on machine-tool slides, was applied to the slide surface with a felt applicator.

The coefficients of static friction shown in the data in Table I and in the typical curves in Figs. 5 and 6 were obtained in the following manner:—

After surface preparation the slider was placed in the saddle on the slide and a 10-lb weight was attached to the suspended rod. The slider assembly was then moved to a position on the quadrant end of the slide. At the instant the slider assembly came to rest a timer was started. Operation of the supply valve to the pneumatic cylinder elevated the quadrant end of the slide until the static angle θ_s was reached. The timer was stopped when the point of instability had been reached, i.e., the point at which the slider assembly started to move down the slide. The time read on the timer was the elapsed time at rest, and the angle θ read on the quadrant was θ_s, from which μ_s was obtained.

Each material pair was run, keeping the time at rest constant, until stabilization of the static coefficient with respect to initial wear had been obtained. Subsequently, the time at rest was extended by delaying the elevation of the slide for intervals of 0·1, 0·2, 0·3, 0·5, 1·0, 2·5, and 5·0 min, with a minimum of three tests at each interval. Various long-time tests at rest under load, for periods of from 1·0 to as much as 144 hr, were run whenever possible. This procedure was repeated, using a 30-lb and a 50-lb load for each slider material on each of the three slides. Whether the load was applied on the suspended rod or directly on top of the slider, the frictional data obtained were identical.

The initial constant-time-at-rest tests and the subsequent extended-time-at-rest runs respectively permitted investigation of the relation of static friction to initial wear and to time at rest (Figs. 7 and 8).

In the lubricated tests, lubricant was redistributed with a felt pad between each run to achieve a degree of uniformity throughout the lubricant film. Both the slides and the sliders were also cleaned and relubricated between each load increment. When testing the frictional characteristics of seventeen plastics with a modified crossed cylinder apparatus, Milz and Sargent[7] found a general decrease in friction values as lubrication was changed from dry to water to oil.

Time and Wear

The coefficient of static friction for flat surfaces varies with respect to wear and the length of time at rest under load prior to break-away. Both factors contribute to the erratic behaviour often encountered in friction analysis and application. In preliminary attempts to obtain coefficients of static friction for these materials, the authors encountered this inconsistency, which led to the plotting of coefficients of static friction obtained in

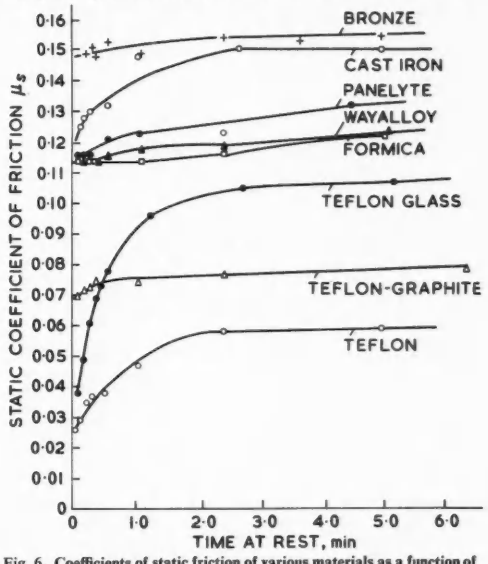

Fig. 6. **Coefficients of static friction of various materials as a function of time at rest under load on a ground cast-iron slide, under lubricated conditions and a 50-psi load.**

TABLE I: STATIC COEFFICIENTS OF FRICTION OF VARIOUS MATERIALS, WITH A TIME AT REST OF 1 MIN

MATERIAL	CONDITION	GROUND CAST IRON			SCRAPED CAST IRON			GROUND STEEL		
		LOAD			LOAD			LOAD		
		10 lb	30 lb	50 lb	10 lb	30 lb	50 lb	10 lb	30 lb	50 lb
Glass-filled Teflon	Dry	0·151	0·150	0·148	0·075	0·084	0·091	0·169	0·144	0·140
	Lub.	0·125	0·107	0·090	0·112	0·103	0·094	0·114	0·106	0·095
Teflon	Dry	0·087	0·079	0·079	0·075	0·070	0·070	0·123	0·102	0·087
	Lub.	0·074	0·051	0·046	0·114	0·096	0·098	0·123	0·096	0·079
Graphite-filled Teflon	Dry	0·079	0·073	0·076	0·135	0·132	0·130	0·126	0·110	0·110
	Lub.	0·088	0·086	0·075	0·102	0·093	0·084	0·102	0·107	0·087
Formica	Dry	0·129	0·136	0·139	0·112	0·119	0·123	0·151	0·222	0·220
	Lub.	0·130	0·118	0·114	0·137	0·130	0·130	0·124	0·123	0·123
Wayalloy "A"	Dry	0·150	0·149	0·151	0·098	0·105	0·105	0·148	0·164	0·194
	Lub.	0·132	0·119	0·116	0·121	0·105	0·107	0·124	0·123	0·121
Bearing Bronze	Dry	0·296	0·276	0·260	0·259	0·259	0·250	0·287	0·306	*
	Lub.	0·143	0·148	0·150	0·167	0·196	0·211	0·100	0·096	0·098
Cast Iron	Dry	0·330	0·325	0·350	0·169	0·200	0·202	*	*	*
	Lub.	0·114	0·123	0·142	0·140	0·144	0·130	0·114	0·126	0·123
Panelyte	Dry	0·119	0·114	0·123	0·114	0·105	0·114	0·167	0·171	*
	Lub.	0·135	0·130	0·123	0·146	0·132	0·132	0·128	0·126	0·127

* Denotes increasing coefficient on successive tests.

successive tests. Typically, these graphs (see the dashed lines in Fig. 8) indicated that μ_s varies with respect to the length of time the slider has been at rest under load prior to break-away. From such graphs it also became evident that the static friction varied with respect to initial wear and in some cases continued to increase with continued testing. Fig. 8 illustrates a case in which the static friction initially showed a decrease and subsequently reached a stable value.

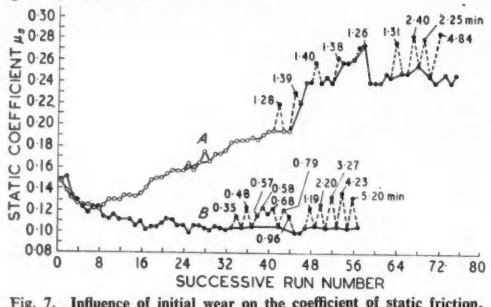

Fig. 7. Influence of initial wear on the coefficient of static friction, showing progressive wear in successive tests with a Panelyte slider on a hardened and ground steel slide, using a load of 30 psi.
(*A*) Dry conditions. (*B*) Lubricated conditions.
The dashed lines indicate extended time at rest.

In order to incorporate time and wear effects into the static friction tests, a procedure as previously mentioned was adopted. By maintaining constant the time at rest under load, the effect of initial wear was observed. As wear progressed in a pair of materials, the coefficient of static friction μ_s varied according to a pattern in which it either initially decreased and became stable, initially increased and became stable, or remained unchanged. A tabulation of the change in μ_s with initial wear was made, and it was found that pairs of materials for which values of μ_s were listed as decreasing with initial wear followed a pattern like that exhibited by dry Panelyte on hardened and ground steel (Fig. 7), while for pairs with μ_s listed as decreasing, Fig. 8 was typical.

Referring again to Fig. 8 it can be noted that the change in μ_s with initial wear can be substantial, up to 100% in some cases. For example, μ_s for Formica tested dry on hardened and ground steel with a contact load of 30 psi (Fig. 8) was 0·146 in the first test, 0·140 in the third and fourth tests, and 0·210 in the forty-seventh test, a stable value of 0·212 being obtained in subsequent tests. Initial wear for a given material varied with respect to the magnitude of the load. The data plotted in Fig. 8 typically indicate that initial wear increased with an increase in load. After this sequence of tests had been completed with the 50-lb load, it was not possible with the same slider to repeat the test with the 10-lb load and obtain the low coefficient of friction as before. Using the same pair of slider and slide materials, the coefficient of friction was nearer 0·19 in further tests with the 10-lb load. It should also be mentioned that the wear which occurred in the tests with 30-lb loads influenced the data for the 50-lb load tests. Addition of a lubricant tends to reduce initial wear and consequently the degree of change in μ_s with initial wear. Initial wear is still present, as indicated in Fig. 7 for lubricated Panelyte.

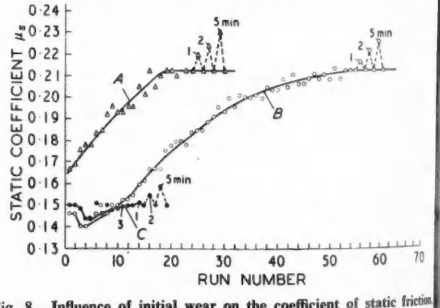

Fig. 8. Influence of initial wear on the coefficient of static friction, showing progressive wear in successive dry tests with a Formica slider on a hardened and ground steel slide.
(*A*) 50-psi load. (*B*) 30-psi load. (*C*) 10-psi load.
The dashed lines indicate extended time at rest.

With regard to continued change in μ_s with progressive wear, cast iron and bronze exhibited the most marked increase, which was most pronounced when the tests were run dry. With the harder plastics, such as Panelyte and Wayalloy "A", μ_s also increased with continued dry testing. The changes in μ_s with respect to the wear produced by successive tests can be attributed to surface changes such as those caused by material transfer. Changes in the slide surface can be analysed by comparing the surface profiles. Material transfer was visually observed in inspections of the slide and slider.

With certain material combinations, the coefficient of static friction attained a stable value after initial wear, and it was noted that μ_s for these materials increased as the interval at rest under load was increased. Thus, some of the curves shown in Figs. 5 and 6 indicate an initial change in μ_s for intervals at rest of from 1·0 to 1·5 min, with a smaller rate of change for intervals from 1·0 to 5·0 min. Extended periods at rest, ranging from 1 to 48 hr, indicated increases in μ_s, but at smaller rates.

Teflon-base materials exhibited the largest rate of change in μ_s with time at rest. For lubricated Teflon under a contact load of 30 psi, the rate of increase in μ_s for intervals at rest of 0·1 to 1·0 min was $2{\cdot}50 \times 10^{-2}$ per min; for 1·0 to 5·0 min, $5{\cdot}10 \times 10^{-3}$ per min; and for 5 to 75 min, $2{\cdot}80 \times 10^{-4}$ per min. When the behaviour of Panelyte, which is representative of the harder plastic bearing materials, was tested under lubrication with a contact load of 30 psi, μ_s changed at a rate of $1{\cdot}88 \times 10^{-2}$ per min for intervals at rest of 0·1 to 1·0 min; $7{\cdot}50 \times 10^{-4}$ per min for 1·0 to 5·0 min; and $7{\cdot}00 \times 10^{-5}$ for 16 hr. The plastics exhibited the largest rate of increase in μ_s with increased time at rest. Aluminium bronze and cast iron also showed a tendency for μ_s to increase, but at a lesser rate, when at rest for prolonged time.

The addition of a lubricant increased the effect of time at rest. It was found that μ_s in the lubricated tests varied to a greater extent than in the dry tests and that increases in load decreased the variation. This is logical since, in the lubricated tests, extrusion of lubricant from the interface occurs, in addition to the plastic deformation and atomic migration present in the dry tests.

Each material combination produced different rates of changes in μ_s, mainly because of the difference in surface conditions. Teflon-type materials exhibited the largest rates of change in μ_s because of the low yield strength of Teflon. This would account for the restricted extrusion of lubricant resulting from the conforming of plastic to the surface irregularities of the metal slide. In contrast, the metals, having greater yield strength, better maintain original surface profiles and thus provide for a less restricted extrusion of the lubricant. The harder plastics are intermediate, because of yield strength lower than that of cast iron or bronze, but higher than the Teflon-type plastics.

Surface profiles and plastic yield stresses of the materials account for the difference in the rate of change of μ_s with time. Those materials with low strength, such as the Teflon group, deformed plastically to conform to the surface profile of the slide. For lubricated tests this mating of the surface would provide maximum resistance to extrusion of the lubricant, while the materials with higher strength, such as Wayalloy, would maintain a surface profile which would tend to remain unchanged and to provide a lower resistance to lubricant extrusion. Accordingly, with bronze and cast iron the extrusion resistance would be minimum.

The break-away characteristic of a material is dependent on the difference between the static and kinetic friction. The kinetic coefficient of friction μ_k can be expressed as $\mu_k = \mu_s - a/(g \cos \theta)$, where a is the acceleration. From the acceleration curve, the value of the acceleration at any point can be obtained for use in the equation to determine the kinetic coefficient of friction.

An interesting phenomenon was obtained in the analysis of the time-displacement charts. The materials exhibited velocity variations which, in turn, indicated negative accelerations. From the dynamic equilibrium equation, a deceleration would require a kinetic coefficient of friction higher than the static coefficient of friction. Although this is contrary to most current friction theories, accuracy checks on the system merely confirmed this phenomenon. Further investigation of this unusual behaviour is warranted. However, it is often found, when taking power data on machine-tool drives, that there is an instantaneous power increase. This can also be experienced in cranking the handwheel of a machine-tool slide with one hand, when suddenly both hands are required to overcome a rough spot or sticking, the generally accepted explanation being usually a poor fit, lack of lubrication, or loose particles. These test results indicate that there is not just one value of μ_k for a flat surface, but that it is possible for the slider to operate under a situation in which momentarily μ_k is larger than the value of μ_s at which it started to move. An increase in the coefficient of friction with speed was found by Boyd[8] when testing S-Monel stationary sliders operating under continuous-slide conditions against stainless steel.

Burwell and Rabinowicz[9] reported tests which showed that the friction force is a function of the normal load and the sliding speed. When measuring the coefficient of friction in relation to the distance of sliding, Rabinowicz[10] established values for μ_k near or equal to μ_s for copper on copper, mild steel on copper, and mild steel on titanium under dry and lubricated conditions.

The experimental evidence of I-Ming Feng[11] in his tests on metal transfer and wear has been substantiated by the investigation reported here. Roughening of the interface due to plastic deformation, the matching and interlocking of the interface, and the effect of regions of severely strain-hardened metal near the interface will contribute to the observed variations of the coefficients of friction.

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SWITZERLAND

Tests on a Bearing with Three Wedge Films

By H. H. Ott. (From *The Brown Boveri Review*, Vol. 44, No. 4/5, April/May 1957, pp. 225–234, 16 illustrations).

The present stage in the development of steam turbines for the generation of electrical power is characterized by a continuing trend towards larger units, involving heavier demands on the turbine and generator bearings. The following article describes the construction of a test rig for large journal bearings and the test results obtained on a bearing having three wedge films.

THE hydrodynamic theory which underlies the oil film furnishes the directives for the development of plain bearings. Present-day knowledge of oil-film behaviour is not so complete as to justify the abandonment of laboratory tests, particularly when very heavy demands are imposed. Thus, it is essential for new bearing designs to be thoroughly tested before they are employed in practice.

CONSTRUCTION OF TEST RIG

The purpose of the test plant is to measure the frictional losses of journal bearings with respect to load, shaft speed, inlet temperature, and delivery pressure of the lubricating medium. The basic layout of the plant can be seen in Fig. 1. The test bearing *A* sits freely on shaft *B*, which is supported by fixed end bearings *C*. The shaft is driven from one end by an electric motor *D* ; a gear-wheel *E*, attached to the opposite end of the shaft, is part of a barring gear (for rotation at very low speed). The test bearing is loaded with the desired pressure by means of the oil-operated piston *F*, via linkage *G* and a yoke *H*. The effective friction torque on the bearing shells can be calculated from the force exerted on scale *J* and the length of the lever.

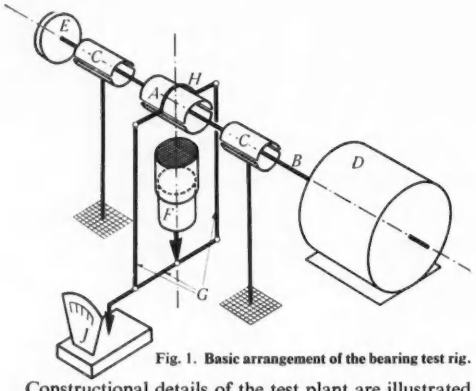


Fig. 1. Basic arrangement of the bearing test rig.

Constructional details of the test plant are illustrated in Fig. 2 ; the diameter of the shaft is 355 mm, and bearings up to 450 mm in width can be examined. Bearings having three wedge films, with considerable bearing strength and good stability, are employed for supporting the shaft at the ends. The bearings are built in the same way as the test bearing to be described later. Knife-edges form the fulcrums of the moving linkage for loading the bearing and for transferring the friction torque to the scale. The oil piston for loading the test bearing is supplied from a high-pressure pump, capable of producing a load on the bearing of up to 100 tons. The shaft is driven by an electric motor, steplessly variable up to 3600 rpm, with a maximum output of 400 kW.

The complete lubricating system of the test rig is shown diagrammatically in Fig. 3. The test bearing and the end bearings which support the shaft are supplied from two separate similar systems which are provided with identical measuring equipment ; thus, at the test bearing it is feasible to vary, over a wide range, working conditions with respect to oil pressure and temperature, while the end supporting bearings run under optimum conditions.

The lubricating and cooling oil for controlling the oil-inlet temperature is delivered by a gear pump through the oil cooler to the measuring nozzle by way of a constant-pressure valve. The oil arrives at the bearing via a pressure-control valve, a jointed connection to the yoke, and a lead-in from the yoke to the bearing. After it has fulfilled its lubricating and cooling duty, the oil collects in the bath and flows back to the reservoir. The inlet pressure is measured at the point where the oil enters the housing and in the flexible connection. The amount of oil is measured by a specially shaped, calibrated nozzle having a constant discharge coefficient in the case of the small Reynolds numbers encountered. The effective head of this throttling device is measured in a U-tube, thus utilizing the lubricating oil itself as the indicating fluid. Oil temperatures at inlet and outlet are measured with built-in thermocouples. At the outlet, the temperature is measured in the return connection, between the housing and the oil reservoir, so that the temperature obtained is that of the mixture. A compensated electronic recording potentiometer, having a range from 0 to 120°C and a recording accuracy of 0·5°C, registers the temperatures.

In addition, the test rig is equipped with a high-pressure lubricating system, similar to that fitted to steam turbines for use when starting, and with the barring gear.

As already mentioned, a pressure-oil-operated piston is employed to load the test bearing. The connection is provided with a constant-pressure valve, which, together with a stop valve, enables any desired pressure to be selected via the load piston. The bearing load is the sum of the oil force at the piston and the weights of all parts suspended with the bearing from the shaft (bearing, yoke, linkage, and piston).

Shaft speed is measured at the driving end with a precision hand tachometer. Torque is measured with a direct-indicating scale, in which the point of load suspension is shifted in relation to the applied weight. Thus, when the lever of the bearing-testing machine is connected directly with the point of suspension of the scale, there is a somewhat different lever position for every torque. In this way, the centre of gravity of the very heavy yoke turns and applies at the bearing shell an additional torque. To eliminate this varying value (i.e., that of the lever) an adjustable distance-piece is incorporated between the lever and the scale, and the lever is provided with a sensitive spirit-level. Longitudinal adjustment of this distance-piece is carried out before each test. However, the asymmetrical distribution of the weight of all the components associated with the test bearing prevents the centre of gravity from passing exactly through the axis of the bearing ; a torque is still manifest. This constant " zero torque " can be determined by rotating the shaft very slowly (without load) and extrapolating with respect to zero speed; it can also be measured when the shaft is stationary, provided the high-pressure lubrication is switched in. The zero torque must be subtracted from all torque readings.

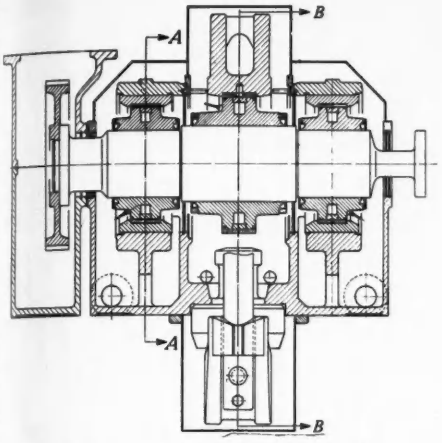
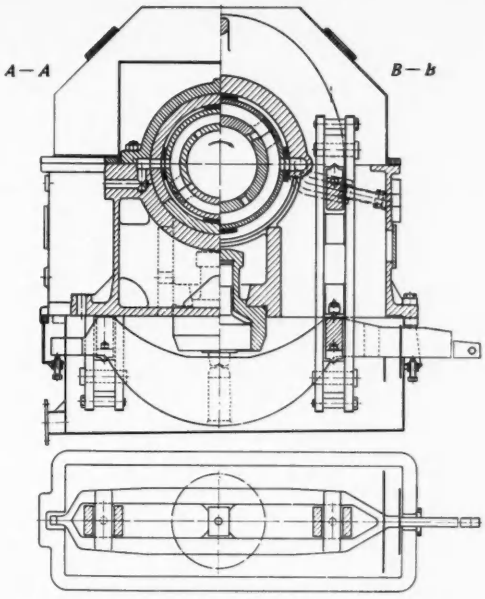


Fig. 2. Constructional details of the bearing test rig.

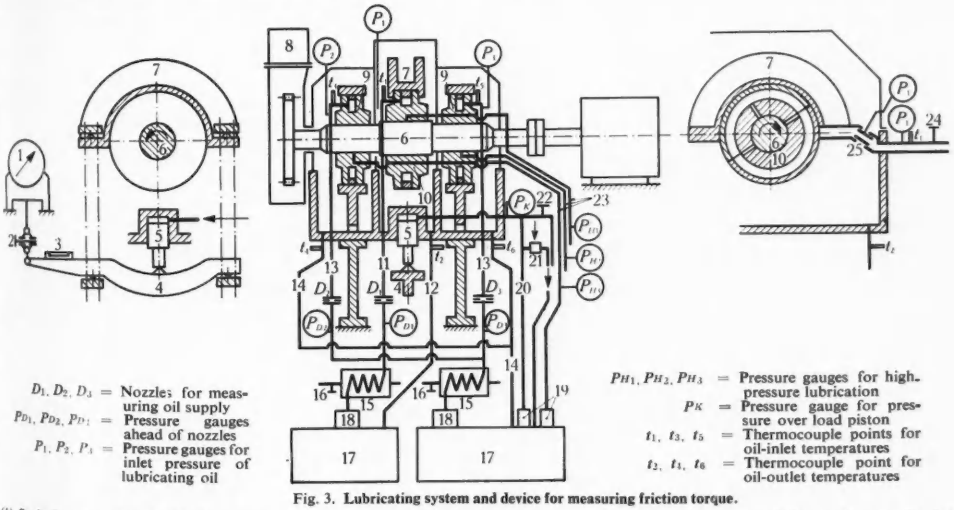
The electrical output of the driving motor, taking into consideration the known motor efficiency, can be used for checking the work lost in friction calculated from the temperature rise of the oil passing through the bearings.

Normally, an essential requirement for measuring the work lost in friction at the shaft from the torque measurement at the bearing is the relative displacement of the bearing shell, at right-angles to the direction of the load, with respect to the shaft. However, since bearings with three wedge films, by virtue of their special design, are distinguished by a negligibly small shaft displacement with respect to the bearing-shell centre, provided the loads are moderate, the torque measured at the shell will in this case be equal to the friction torque at the shaft.



Tests on a Three-Wedge-Film Bearing

This bearing has three wedge segments, arranged round the periphery, as shown in Fig. 4. Each segment exerts a resultant oil pressure on the shaft, so that it rotates in a most stable manner. The three segments are of unequal length, since with turbo-machines the direction of the load which the bearing must withstand is decided in advance.



D_1, D_2, D_3 = Nozzles for measuring oil supply
P_{D1}, P_{D2}, P_{D3} = Pressure gauges ahead of nozzles
P_1, P_2, P_3 = Pressure gauges for inlet pressure of lubricating oil
P_{H1}, P_{H2}, P_{H3} = Pressure gauges for high-pressure lubrication
P_K = Pressure gauge for pressure over load piston
t_1, t_3, t_5 = Thermocouple points for oil-inlet temperatures
t_2, t_4, t_6 = Thermocouple point for oil-outlet temperatures

Fig. 3. Lubricating system and device for measuring friction torque.

(1) Scale for measuring the friction torque
(2) Adjustable coupling
(3) Spirit level
(4) Lever for transferring friction torque
(5) Load piston
(6) Shaft
(7) Yoke
(8) Barring gear
(9) Side supporting bearings
(10) Test bearing
(11) Oil supply to test bearing
(12) Oil discharge from test bearing
(13) Oil supply to side bearings
(14) Oil discharge from side bearings
(15) Oil cooler
(16) Cooling-water control valve
(17) Oil reservoir
(18) Lubricating-oil pump with constant-pressure valve
(19) High-pressure oil pumps
(20) High-pressure-oil connection to the load piston
(21) Constant-pressure valve
(22) Valve for controlling oil pressure to load piston
(23) Oil-supply connections for high-pressure lubrication
(24) Oil-pressure control valve
(25) Flexible connection for oil supply

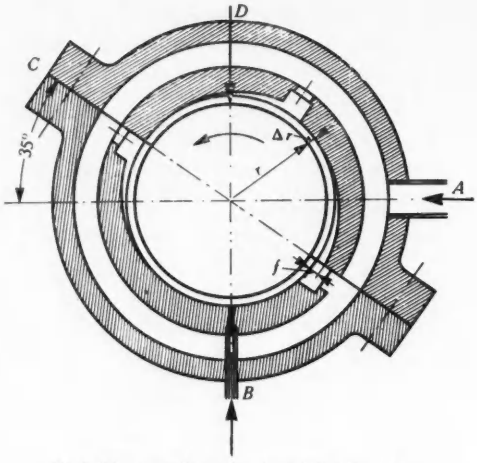


Fig. 4. Diagrammatic section through test bearing.
A = Oil inlet for normal lubrication
B = Oil inlet for high-pressure lubrication
C = Joint
D = Direction of load

The choice of fundamental film form, whose development can be seen in Fig. 5, is based on the resultant oil-film pressure and coefficient-of-friction calculations. The ratio of wedge length s_1 to segment length s is approximately 0·7. The depth f of the wedge at the entry is 1·5 Δr ; Δr is the radial clearance between the shaft and the cylindrical part of the segment. The bearing tested has a relative clearance $\Delta r/r = 0{\cdot}0012$. Fig. 6 illustrates the wedge-shaped section of a segment, with cylindrical (i.e., concentric) edges, and oil inlet. The oil-distributing grooves have lateral pressure-relieving openings, which are shown in the drawing. The width/diameter ratio $\beta = 1{\cdot}15$.

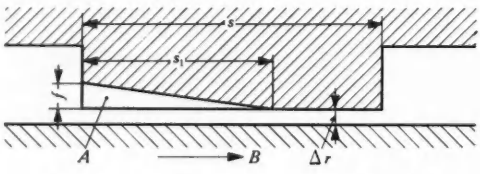


Fig. 5. Projected basic shape of tapered film.
A = Edge
B = Direction of rotation of moved surface

The inclination of the bearing joint is dictated by the high-pressure lubrication. The oil is introduced at the lowest part of the bearing, on which the shaft rests when stationary, and the inlet opening must be in the cylindrical part of the 180-deg. segment.

The advantages of this type of bearing are extremely stable running, the ability to withstand heavy loads, and almost concentric rotation up to considerable loads.

Test Results and Evaluation

In these tests, carried out with standard turbine oil, a uniform inlet temperature of 50°C was maintained with only slight deviations, as can be seen from Fig. 7. The excess oil-inlet pressures were varied between 0·5 and 2·5 bars. The test results given in Fig. 7 for the three speeds, i.e., 1000, 2000, and 3000 rpm, were obtained with the three specific loads, i.e., 1·45 (pressure-piston unloaded), 11·0, and 20·5 bars. The recorded friction torques at the bearing

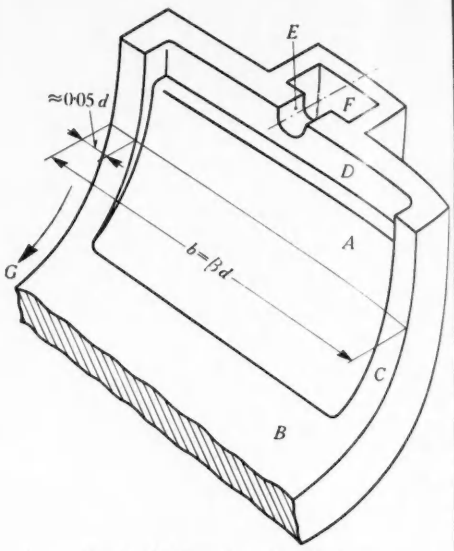


Fig. 6. Friction surface of test bearing.
A = Tapered part of friction surface
B = Cylindrical part of friction surface
C = Cylindrical (i.e., concentric) edge
D = Oil-distribution groove
E = Oil inlet
F = Surrounding channel for oil supply
G = Direction of rotation of shaft

shell, the oil throughput, and the temperature rise can be seen in Figs. 7a, b, and c, respectively.

In plain bearings, the frictional phenomena can be represented by dimensionless values by setting the coefficient of friction μ/ψ (related to the relative bearing clearance) over the dimensionless bearing load $p_m\ \psi^2\ (\omega\eta)$.

The coefficient of friction of a bearing is defined as

$$\mu = R/P \qquad .. \qquad .. \qquad (1)$$

where R is the total frictional force at the periphery and P represents the total load carried by the bearing. The relative bearing clearance is given by

$$\psi = \Delta d/d = \Delta r/r \qquad .. \qquad .. \qquad (2)$$

where, in this case, $\Delta d = 2\ \Delta r$ must be measured between the shaft and the cylindrical parts of the bearing surfaces. The value $d = 2r$ refers to the shaft diameter. For the bearing under consideration Δr can be regarded as a characteristic dimension for the oil-film form, provided the wedge depth f (see Fig. 5) has a definite relationship to the radial clearance Δr. The load factor Π_m of the bearing, also known as Sommerfeld's number, is

$$\Pi_m = \frac{p_m\ \psi^2}{\omega\eta} \qquad .. \qquad .. \qquad (3)$$

The value p_m is the mean specific load related to the projected surface of the bearing and

$$p_m = \frac{P}{b\ d} \qquad .. \qquad .. \qquad (4)$$

where b refers to the actual bearing width. ω defines the angular velocity of the shaft, and η is the "mean" dynamic viscosity of the lubricating medium. Since the viscosity of oil varies according to the temperature, it is difficult to decide on the physically correct reference temperature for the viscosity, particularly when, as is the

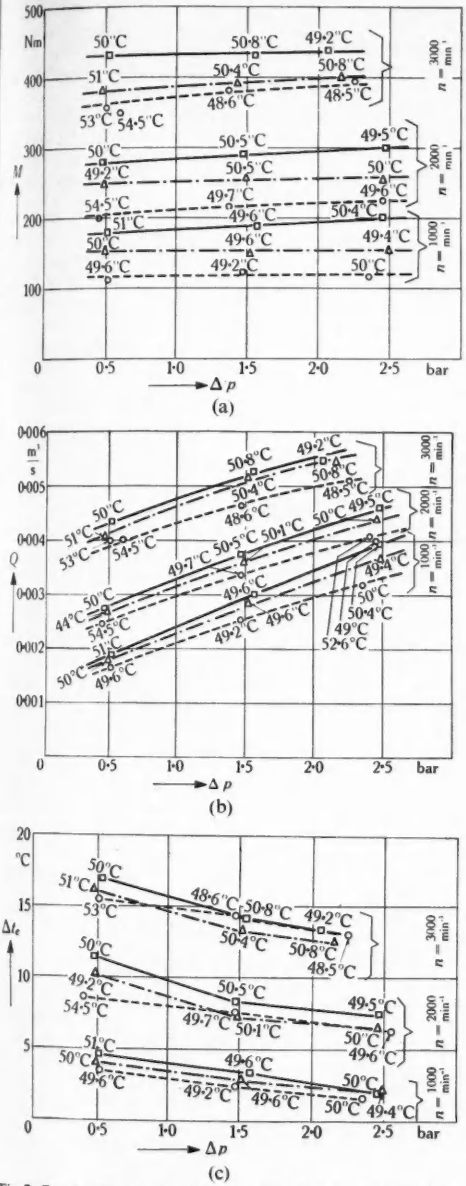


Fig. 7. Results of tests on bearing at various speeds n, showing (a) friction torque M, (b) quantity of oil Q passing through bearing, and (c) temperature rise in bearing, related to excess pressure Δp at the inlet.

Shaft diameter – – – – – – – 355 mm
Bearing width – – – – – – – 410 mm
Relative bearing clearance – – – 0·0012

Inlet temperatures in °C are stated in the graph.

○ : p_m = 1·45 bars Δ : p_m = 11·0 bars □ : p_m = 20·5 bars

case here, some of the oil is circulated solely for cooling purposes, mixing in the bearing housing again before leaving, without entering the gap. Since the object of this study is to establish the simplest possible basis for calculation, this difficulty is avoided by developing the load factor with the viscosity at the entrance η_E. Thus, the characteristic factor is defined as

$$\Pi_m = \frac{p_m \psi^2}{\omega \eta_E} \quad .. \quad .. \quad (5)$$

This is conducive to straightforward conditions, not only for evaluating the test results, but also for applying them to the advance calculation of the work lost in friction. The calculation of the frictional force R at the shaft from the friction torque M measured at the bearing shell, in accordance with the equation

$$R = M/r \quad .. \quad .. \quad .. \quad (6)$$

is then strictly correct, when the effective resultant oil forces on the bearing shell and on the shaft are located in the same axis. An unpublished investigation shows that, in the case of this particular bearing, the value of the displacement Δx is so small that the difference between the moments at the shaft and those at the bearing shell can be neglected. Thus, the values of R and M for the shaft and the shell in eq. (6) are the same.

The coefficients of friction at all measuring points are plotted in Fig. 8. It will be observed that the μ/ψ values can be represented by a single curve, so that the influence of Δp is so insignificant that it can be ignored. The power loss in the bearing for every operating condition can be obtained instantly from the curve, in accordance

$$N = \mu P r \omega \; .. \quad .. \quad .. \quad (7)$$

To arrive at a dimensionless representation of the oil throughput, it is assumed, for the sake of simplicity, that all the oil supplied to the bearing leaves the film (i.e., the gap) axially. The excess pressure Δp obtains in the three distribution grooves of the bearing. It is known from the theory concerning infinitely wide, wedge-shaped oil films that the mean oil pressure p_{ms} in the segment has the value

$$p_{ms} = \Delta p + p_{msu} \; .. \quad .. \quad (8)$$

where p_{msu} refers to the mean pressure obtaining in the segment in the case of oil inflow and outflow without excess pressure, i.e., $\Delta p = 0$. The quantity of oil dQ leaving a definite point at the edge of a bearing segment is given for laminar flow by

$$dQ = \frac{1}{12\eta} \left(\frac{\partial p}{\partial z} \right) h^3 r \, d\varphi$$

where h represents the local film height, z the co-ordinate at right-angles to the direction of movement of the shaft surface, and $d\varphi$ the angle [radians] of the element considered. It is assumed, in this instance, that the viscosity η is constant.

Limiting the consideration to bearings having the same width ratio, with similar gap form and the same relative shaft position, the tangent line of the axial pressure $\partial p/\partial z$ at a definite point at the edge is approximately proportional to the mean pressure in the segment and inversely proportional to the shaft radius. Moreover, the local film heights are proportional to $r\psi$. Thus, dQ can be written as

$$dQ = k_1 \frac{p_{ms}}{\eta} r^3 \psi^3 \, d\varphi \quad .. \quad .. \quad (9)$$

where k_1 is a dimensionless factor of proportionality which is dependent on the position of the edge element. When p_{ms} is introduced from eq. (8), the same applies for the two edges, for the full length of the segment, i.e.,

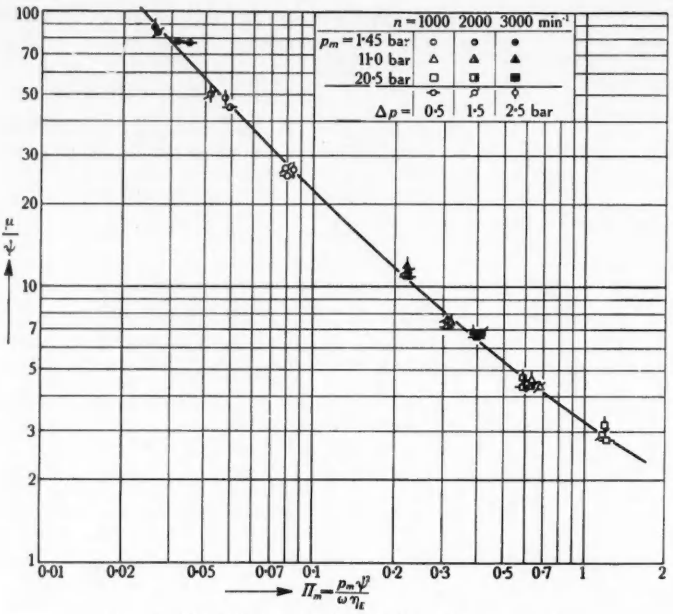


Fig. 8. Coefficient of friction μ of test bearing with respect to load.

This derivation, which is approximate in character, is valid for all bearings having three wedge films with geometrically similar dimensions. It can now be assumed, however, that, from a certain minimum onwards, the slope of the oil-pressure tangent line is no longer greatly dependent on the axial width of the bearing, so that the function $F\,[\Pi_m\ ;\ \Delta p\psi^2/(\omega\eta)]$ can also be applied to bearings whose width ratios differ from those of the bearing under consideration.

Based on the foregoing derivation and eq. (12) the value

$$Q_0 = r^3\,\psi\,\omega \quad .. \qquad .. \quad (13)$$

is introduced as a reference value for the oil throughput and

$$\delta = \frac{Q}{Q_0} = \frac{Q}{r^3\,\psi\,\omega} \quad .. \quad (14)$$

is defined as the characteristic oil throughput value.

$$Q_s = k_2\,\frac{r^3\,\psi^3}{\eta}\,(\Delta p + p_{msu}) \quad .. \quad (10)$$

where k_2 is a dimensionless constant which is dependent on the shaft position. For a given relative position of the shaft, the value $[p_{msu}\,\psi^2/(\omega\eta)]^2$ has a constant value for a segment of the bearing, so that

$$p_{msu} = k_3\,\frac{\omega\,\eta}{\psi^2}$$

Thus, eq. (10) can be written as

$$Q_s = k_2\,\frac{r^3\,\psi^3}{\eta}\left(\Delta p + k_3\,\frac{\omega\,\eta}{\psi^2}\right)$$

The oil quantities Q_s of the individual segments must be added in order to obtain the total flow of oil from the bearing, so that

$$Q = \frac{r^3\,\psi^3}{\eta}\left(k_4\,\Delta p + k_5\,\frac{\omega\,\eta}{\psi^2}\right)$$

This formula can be rewritten

$$Q = r^3\,\psi\,\omega\left(k_4\,\frac{\Delta p\,\psi^2}{\omega\,\eta} + k_5\right)$$

where k_4 and k_5 are dimensionless constants, dependent on the shaft position. However, in the first approximation this is dependent solely upon term $\Pi_m = p_m\,\psi^2/(\omega\,\eta)$; thus,

$$\frac{Q}{r^3\,\psi\,\omega} = F_1(\Pi_m) + \frac{\Delta p\,\psi^2}{\omega\,\eta}\,F_2\,(\Pi_m) \;..\; (11)$$

or, expressed in general terms,

$$\frac{Q}{r^3\,\psi\,\omega} = F\left(\frac{\Delta p\,\psi^2}{\omega\,\eta}\ ;\ \frac{p_m\psi^2}{\omega\,\eta}\right) \quad .. \quad (12)$$

According to eq. (12), δ depends on the dimensionless values $p_m\,\psi^2/(\omega\,\eta)$ and $\Delta p\psi^2/(\omega\eta)$. These dimensionless values can be related to the inlet viscosity, and the required relationship can be written in symbolic form as

$$\delta = F\left(\frac{\Delta p\,\psi^2}{\omega\,\eta_E}\ ;\ \frac{p_m\,\psi^2)}{\omega\,\eta_E}\right) = F\left(\frac{\Delta p\,\psi^2}{\omega\,\eta_E}\ ;\ \Pi_m\right) .. \quad (15)$$

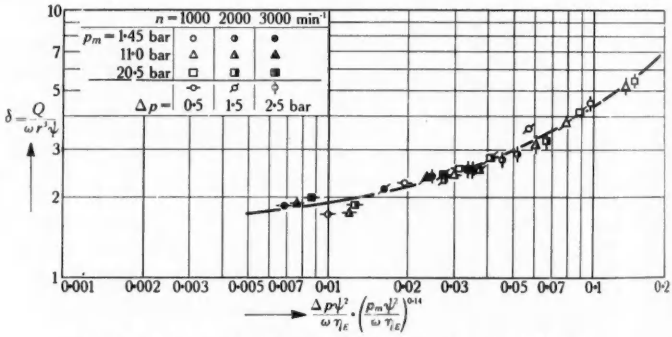


Fig. 9. Graph for determining quantity of oil passed through test bearing.

It was seen from the evaluation that an arrangement having the form

$$\delta = F\left(\frac{\Delta p\ \psi^2}{\omega\,\eta_E}\ \ \Pi_m^{\,a}\right) \quad .. \quad .. \quad (16)$$

is feasible in place of the general eq. (15). The value $a = 0{\cdot}14$ is obtained for the exponent from a parametric representation of the measured points in a log-log system having the axes $\Delta p\psi^2/(\omega\eta_E)$ and Π_m. In Fig. 9 the characteristic factor δ is plotted.

The satisfactory plotting of the measured points underlines the usefulness of the inlet viscosity as a reference value. The knowledge of δ now permits the oil

(*Concluded on page 348*)

The ONERA Process of Skin Annealing in a Gaseous Atmosphere

By P. GALMICHE. (From *La Recherche Aéronautique*, No. 59, July-August, 1957, pp. 27-32, 15 illustrations.)

In a report[1] published in 1954, it is noted that there has been an increase in corrosion-cracking phenomena in the heat-resistant alloys used for the rotating blades of aircraft gas turbines at the increasingty high temperatures to which these components are subjected. This report also indicates the causes and the mechanism of crack-forming intergranular corrosion in high-temperature nickel-chromium alloys of the modified 80/20 type, mostly used nowadays in turbine-blade manufacture.

It has been found that intergranular corrosion of these alloys is associated with a local decrease in chromium content along the grain boundaries, owing to preferential precipitation of carbides and of a certain quantity of Ni_3Al-Ti compounds (without chromium), which take part in the structural hardening of the matrix.

The blades of aircraft gas turbines are in most cases machined from blanks which have been previously forged and solution-treated at temperatures in the region of 1100°C. This machining of the surface can produce considerable work-hardening over irregularly distributed areas and is therefore capable of affecting service behaviour, particularly in the presence of combustion gases.

Buckle and Poulignier[2] have given evidence of the extent of the structural changes in surface layers which can be caused by work-hardening during machining. It has been noted that, with a machining scratch, corresponding to considerable local work-hardening, the penetration of corrosion is appreciably increased, with corrosion propagating along a new network. This seems to indicate that premature alteration of the material occurs in the areas with the heaviest local work-hardening[3].

However, it has also been shown in Poulignier's investigation that a slight and regular amount of work-hardening of the surface has a favourable character with regard to intergranular corrosion. A slight amount of work-hardening results in a reduction in the depth of intergranular penetration, owing to surface dislocations at the grain boundaries, which are preferential paths in corrosion cracking. However, it has the disadvantage that the number of fine cracks is increased. Thus, there is considerable difference in the appearance of testpieces of 80/20 alloy exposed to combustion gases at high temperatures, according to whether or not the surface layers are even slightly work-hardened.

To neutralize the effect of severe work-hardening, such as may be produced in machining operations, heat-resisting blades of 80/20 alloy are generally subjected to a brief annealing treatment at 1080 to 1100°C, this operation being known as " skin annealing ". Generally, the testpieces are immersed in a bath of boron anhydride and cryolite, and this salt-bath treatment frequently causes appreciable oxidation of the surfaces, with in some cases crack formation and the introduction of undesirable elements such as boron. After annealing, it is then necessary to provide for grinding or mechanical polishing, in order to eliminate the oxides and the surface layers affected by corrosion.

Some manufacturers carry out this subsequent annealing operation in a very pure hydrogen atmosphere. However, the conditions of the treatment are delicate, and it is not possible to avoid some surface oxidation, owing to traces of oxygen or water vapour which may remain in the hydrogen, and the affinity to oxygen of some of the constituent elements of the alloys used.

Based on the fact that corrosion cracking is associated with a local deficiency of chromium, the new ONERA skin-annealing process (which includes an annealing cycle consisting of rapid heating, holding at temperature for a period of some minutes, and rapid cooling) can be performed in two different ways, comprising:—

(1) A chromizing treatment, producing a very slight, uniform, and controlled increase in the chromium content of the surface layers, particularly along the edges of the grain boundaries. It is essential, for the alloys under consideration, to avoid a pronounced enrichment in chromium of the surface layers, such as that obtained in normal chromizing operations, since this would make them brittle, owing to the precipitation of fragile compounds during cooling.

(2) A bright-annealing treatment, which increases the homogeneity of the chromium content of surface layers by removing, in the form of a volatile fluoride, some of the titanium which is the main cause of corrosion cracking in heat-resisting high-temperature 80/20 alloys under the action of the combustion gases.

The ONERA process performed in a gaseous medium is basically simple:—The components are placed in reasonably well-sealed boxes in the presence of protective compounds of fluorine (generally chromium fluoride or nickel fluoride), which are formed *in situ* by introducing metallic fluorides. These are then heated in a hydrogen atmosphere. In the case of the chromizing treatment, a certain additional quantity of chromium is included in the neighbourhood of the components being treated, under conditions permitting control of the amount of chromium contributed.

After this operation, the boxes are cooled under cover with a flow of protective gas surrounding them, the furnace being recharged with a new batch of components during this period. The small installation used at ONERA for this work is capable of treating from 4 to 20 blades per hour, depending on their size. The complete process takes about 30 min. The components taken out of the boxes after treatment show absolutely no traces of corrosion and have a very bright finish, if they are polished before annealing.

The effect of skin annealing on the surface layers of components made from 80/20 alloy varies, as indicated by Buckle and Poulignier. According to the amount of work-hardening to which the components have been subjected, the treatment may either eliminate only surface defects caused by work-hardening or, if sufficient localized work-hardening is present, it may cause true recrystallization, with the appearance of new grains. In all cases and for all grades of alloy treated, the surface layers are " regenerated " by the treatment in a gaseous medium, without any additional detrimental phenomena.

The change in the chemical composition of the surface layers of various 80/20 alloys as a function of the distance below the surface has been accurately determined by Malamand[4], with the combined use of two procedures, i.e., electrolytic polishing (for gradual and uniform removal of surface layers) and spectrographic analysis. The skin-annealing process with a chromizing treatment results mainly in a slight increase in the chromium content of the layers closest to the surface, as well as in

a slight reduction in the titanium and aluminium content, over a depth up to some hundredths of a millimetre. In the case of the bright-annealing treatment, no appreciable variation is observed in the chromium content of the surface layers. The results obtained by Malamand for Nimonic 95 are shown in Figs. 1, 2, and 3.

Further tests have confirmed the protective influence of skin annealing in a gaseous medium against the action of high-temperature combustion gases. The penetration

Fig. 1. Chemical variations in the surface layers of Nimonic 5, obtained by the ONERA chromizing skin-annealing proce .

Fig. 2. Chemical variations in the surface layers of Nimonic 5, obtained by the ONERA bright-annealing process.

Fig. 3. Influence of skin-annealing treatment on the chemi l variations in the surface layers, caused by corrosion, of Nimonic 95 subjected to corrosion at 850° C for 100 hr in air.

- ● Work-hardened testpiece.
- o Testpiece previously subjected to the ONERA chromizing skin-annealing process.
- \+ Testpiece previously subjected to the ONERA bright-annealing process.

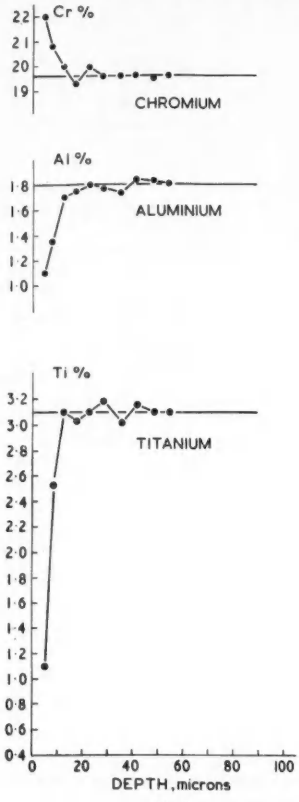


Fig. 1.

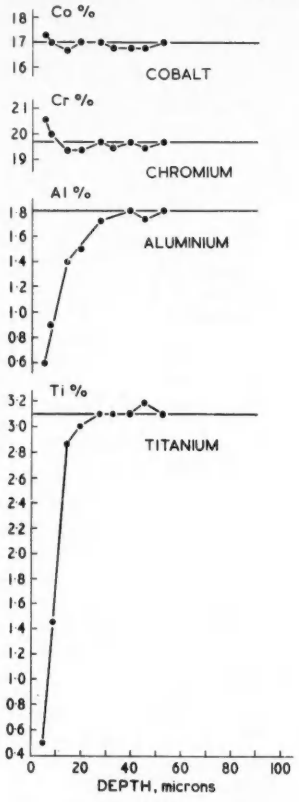


Fig. 2.

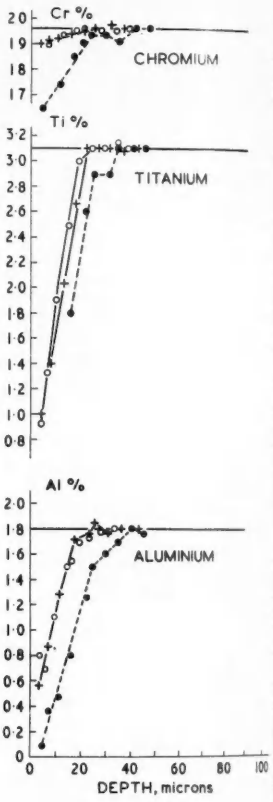


Fig. 3.

depth of corrosion cracking is reduced appreciably, particularly when the chromizing treatment is employed, as is evidenced by micrographic examinations. The reduction in corrosion is due, as previously stated, either to surface enrichment in chromium, initial removal of some of the titanium from the surface layers, or the regeneration of uniform conditions on testpieces with considerable localized areas of work-hardening.

As regards mechanical tests of creep behaviour and fatigue at high temperatures, it may be noted that it is difficult to obtain in a reproducible manner on testpieces the irregular work-hardening conditions which occur in the machining of blades and which justify the use of the skin-annealing process. The general results of these tests, however, have confirmed that the annealing treatment in a gaseous medium does not cause any reduction in creep strength or in fatigue strength at high temperatures, as contrasted with the results sometimes obtained after annealing in a salt-bath process. The results of these various laboratory investigations have also been confirmed by service tests on aircraft turbines[4,5].

Two points to be borne in mind are that (1) the skin-annealing treatment is beneficial for components which have been subjected to rough or irregular machining, particularly when the materials are sensitive to work-hardening, this being the most frequent case; and (2) if the components have been machined gradually and in a very uniform manner, the skin-annealing process has no further advantages, particularly because it removes the slight amounts of uniform work-hardening of the surface which appear to have a favourable effect. Consequently, the skin-annealing treatment for the blades of aircraft gas turbines should be regarded as a " remedy ", rather than as a general improvement (except for protection against dry corrosion cracking), its application depending on the machining conditions of the components.

The fluorinated atmospheres used in the ONERA skin-annealing process are exceptionally effective and

can also be employed for bright annealing, with or without a controlled addition of chromium for most steels and heat-resisting alloys, so as to obtain stress relief, increased homogeneity, etc. in annealing treatments. In the presence of these fluorine-containing reducing atmospheres, no metallic oxide can remain stable at high temperatures, as they are gradually transformed into fluorides which are eliminated or reduced by the hydrogen.

The conditions of operation are generally similar to those used for the skin-annealing treatment in a gaseous medium, with some modifications to suit the particular thermal or thermo-chemical conditions of the application considered. Special provisions can be made to avoid decarburization of the surfaces during annealing or, on the other hand, to achieve uniform decarburization of the surface layers of the components being treated.

Furthermore, mainly because of their appreciable deoxidising action, fluorinated reducing atmospheres can be used to obtain a substantial improvement in the quality of certain treatments, e.g., the sintering of metallic powders, and in particular of stainless-steel or chromium-containing alloys. These atmospheres are already employed on an industrial scale in such applications. Finally, it is conceivable that fluorinated atmospheres can be used as protective media in certain operations such as the forging or rolling of heat-resisting alloys at high temperatures.

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U. S. A.

The Use of "Motocylinders" for Producing Reciprocating Motion

By P. A. RABIDEAU. (From *Westinghouse Engineer*, Vol. 17, No. 4, July 1957, pp. 126–128, 8 illustrations.)

ORIGINALLY developed for the lumber industry to replace costly steam and air cylinders, the "motocylinder" is a simple electromechanical device consisting essentially of an electric motor driving the high-speed shaft of a gear unit, with a crank-arm on the slow-speed output shaft imparting motion to the driven machine. Limit-switches operated by the crank-arm provide the necessary intelligence for stopping and starting the motocylinder at any desired position. If mechanical braking is desired, a disc-type brake is flange-mounted to the motor.

Unlike a flywheel and clutch-press operation, the motor is started and stopped every cycle, obviating any clutches between the motor and load. Some advantages of a motocylinder are : (1) Only electric power is required for complete operation of the drive—a factor that has become of major economic importance in the selection of this type of drive. In most cases the initial investment will be lowest when motocylinders are adopted. (2) No air or oil supplies, with possible leakage and complicated piping, are required. Likewise, standby losses and pressure build-up is not a problem. (3) Cycle times up to 1200 operations per hour are realistic, this duty cycle being possible because the motocylinder is not dependent on system-pressure build-up. (4) Simple harmonic motion is available. (5) Maintenance costs are low because of the simple electromechanical scheme and uncomplicated control required. (6) The motor returns electrical power to the power system during a portion of the cycle period. (7) Both electrical and mechanical braking can be used, with electrical braking having the advantage of lower maintenance and easy adjustment. (8) Because of the simple control, the motocylinder can easily be interlocked with existing control schemes.

The motocylinder has two basic motions, i.e., loads can be moved in a vertical plane or in a horizontal plane, as shown in Fig. 1. Any configuration other than these basic motions is a combination of the two motions. In all cases, load velocity follows a modified sine function, and load acceleration a modified cosine function, as shown in Fig. 2. Load accelerating periods are always from 0 to 90 deg., and 180 to 270 deg. crank rotation. Load decelerating periods are 90 to 180 and 270 to 360 deg.

A feature of this drive is that, during deceleration, the load may be overhauling the motor, so that power is returned to the system. For horizontal movement, power is returned to the system during the decelerating periods only when the friction load is small, because of the counter-torque required from the motocylinder. For vertical motion, the initial decelerating counter-torque (90 to 180 deg.) is aided by the gravitational force of the load, so that little if any power is returned to the system when the load is raised. However, when the load is lowered (180 to 360 deg.), the drive must exert counter-torque continually, and power is returned to the system during the complete lowering period. Consequently, load motion is slowed down by this generating action and load braking, whether mechanical or dynamic, need not be applied until the last few degrees of crank rotation. Thus, when most of the braking is done by the motor, the size of the braking system can be kept to a minimum.

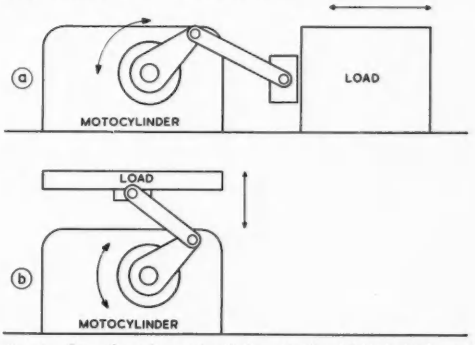


Fig. 1. Operation of a motocylinder, showing (a) basic horizontal motion, and (b) basic vertical motion.

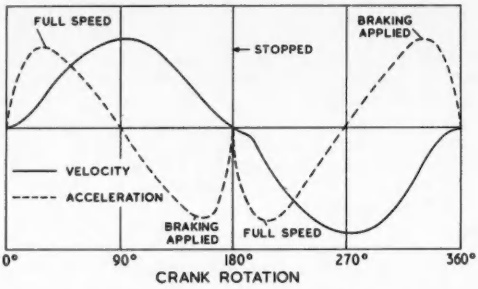


Fig. 2. Load velocity and load acceleration curve for a motocylinder stopped in the 180-deg. position.

The motocylinder drive is a 1200-rpm hoist-type induction motor, totally enclosed and non-ventilated, with a minimum pull-out torque of 275%. The high torque capabilities of this particular motor provide rapid acceleration of the rotor. Because of the crank motion, the inertia of the rotor and the inertia of the load are not accelerated at the same time. Little load inertia is reflected to the motor during initial motor acceleration, and the motor runs up to speed in a few degrees rotation of the crank-arm. Hence, motor accelerating and decelerating losses are kept to a minimum. With the high torque available, the drive can be jogged through the 90-deg. portion of the load cycle, where maximum motor loading exists. Another feature of this design of motor is its inherent capability of starting and stopping rapidly, giving it an advantage in applications where the maximum number of cycles per minute is critical.

Two types of braking can be used with the motocylinder, i.e., the conventional disc-type friction brake, which is flange-mounted to the motor, or dynamic braking. Mechanical braking should be used where an overhanging load when the drive is stopped would cause the system to creep. Of course, the disadvantage of this method is the maintenance required by the brake and the addition of brake-drum inertia to the system, generally reducing the available cycles per hour. When mechanical braking is applied, only a conventional motor starter, interlocked with the motocylinder limit-switches, is required.

Dynamic braking consists of removing the a.c. voltage from the motor and applying direct current to two motor windings. This causes the motor to act as a generator, which is loaded by the induced current flowing through its squirrel-cage rotor winding. The amount of braking is determined by the magnitude of direct current applied. With dynamic braking, no additional mechanical parts are required and more cycles per hour can be obtained, but braking torque is absent at zero speed.

An example of a vertical-motion motocylinder application now in service is a press welder for welding a multiplicity of automotive parts, in which vertical reciprocating motion is imparted by motocylinder-mounted cams and a mechanical knee system. Operation of this press welder is similar to that of a conventional press, except that the press is stopped in the "up" position. The part to be welded is placed in the fixture on the platen while the machine is in the "down" position. The operator initiates the cycle by push-buttons, the crank-arm of the 5-hp motocylinder rotates 180 deg., and the drive is dynamically braked to a stop. The welding guns are brought out automatically and the part is welded, after which the weld timer signals the motocylinder control and the platen is returned to the "down" position, where the welded part is removed. This press welder is capable of operating 1200 cycles per hour. Dynamic braking is used to good advantage in this application. The welder is designed so that, when it is in the "weld" position, the mechanical linkage has an overcentre feature which prevents the downward force of the welding guns from rotating the drive, without the use of a holding brake. Furthermore, this type of linkage does not have accurate stopping requirements.

An example of a motocylinder operating in a horizontal plane is in a transfer machine used in the automobile industry for transferring clutch covers. In this application, the motocylinder drives the transfer mechanism through a rack-and-pinion system which produces horizontal movement of the machine. On the forward stroke, the clutch cover is transferred into the entry side of a press. After the stamping or drawing operation and completion of the return stroke, the clutch cover is removed from the opposite side of the press and transferred to the next press on the following forward stroke. A conventional disc-type brake is used on the motocylinder, because this particular system requires holding torque at zero speed.

An example of the size of motocylinder required for a typical application is afforded by a shuttle-type transfer machine used for transferring engine blocks in a broaching operation. In this application, the total weight to be indexed is 10,000 lb, producing a horizontal friction force of approximately 2000 lb. The cycle is as follows :— The loaded forward stroke transfers the load in 1½ sec ; the drive then remains at rest for 2 sec while the dogs are retracted, the unloaded return stroke is made in 1½ sec, and the final dwell time is 4 sec, when the machining operation is performed. The complete cycle time is thus 9 sec, providing 400 operations per hour, and a 7½-hp motocylinder is quite adequate for the purpose.

Tests on a Bearing with Three Wedge Films

(Concluded from page 344)

throughput to be calculated for every operational condition of the bearing ; unlike the loss of power, this value is largely dependent on the excess pressure of the oil at the inlet Δp. The bearing load, on the other hand, has little effect on the oil throughput.

As regards the measured temperature rises of the oil, the primary question is how the measured temperature difference (i.e., at inlet and outlet) compares with the temperature difference obtained from the heat balance of the bearing, assumed to be heat-retaining. It is thus necessary to compare the measured temperature difference Δt_e with the calculated value Δt_q obtained from

$$N = Q \rho c \Delta t_q \quad .. \quad .. \quad (17)$$

where the specific heat c is related to the mean temperature between inlet and outlet. Based on comparisons between measured and calculated temperature differences, and taking into consideration the measurement tolerances previously mentioned, it can be concluded, in the case of the bearing investigated, that the oil conveys away virtually all the heat caused by friction. Consequently, it is admissible, for technical calculations, to set down the energy balance for oil-cooled plain bearings in the simple form of eq. (17), and the temperature rise of the oil can be calculated in advance from operational data.

Pressure Dependence of the Electrical Breakdown Strength of Hydrocarbons

By H. LUTHER and H. RÖTTGER. (From *Elektrotechnische Zeitschrift* (*E.T.Z.*), Edition A, Vol. 78, No. 13, July 1, 1957, pp. 462–464, 2 illustrations.)

In electrical engineering, hydrocarbons are frequently used as insulating materials. Their insulating properties, however, depend to a considerable extent on the structure of the hydrocarbons and on pressure. In a previous investigation[1], it has been found that at constant pressure the electrical breakdown strength of hydrocarbons is primarily a function of density (which depends on molecular structure) and temperature, the type and quantity of the dissolved gases having little influence on the results. For atmospheric pressure conditions, the following simple formula is valid :

$$E_d = U_L/L = K\,d \quad .. \quad .. \quad .. \quad (1)$$

where E_d = breakdown field strength [kV/cm], L = thickness [cm], U_L = breakdown voltage [kV] with a thickness of 0·2 cm, d = density [gm/cm³], and K = a constant (kVcm²/gm], depending on test conditions.

A similar relationship has been derived by Crowe, Sharbaugh, and Bragg[2] ; the type and amount of gas dissolved also played no major part in their considerations.

In a further investigation, the authors of the present report considered it of interest to determine quantitatively under various pressures the effect of dissolved gases. A procedure was employed which permitted the charging of liquids with specific quantities of gas, and the electrical strengths of a hydrocarbon mixture with various dissolved gases at different pressures were determined.

Test Equipment and Procedure

The apparatus employed for measurements of gas solubilities (Fig. 1) is basically similar to that described by Oetjen and Gross[3]. The normal high-vacuum equipment (1) is connected to a glass column (2), inside which a heating coil (3) is arranged. The liquid to be charged with gas or degassed is drawn via a solenoid pump (4) from the bottom to the upper portion of the column, whence it flows as a thin film or layer over the coil. For degassing, the column is connected via a cock (5) to the vacuum pump (1) and the gas receiver (6) behind it, in which the quantities of gas withdrawn after passing several times through the system are determined manometrically. For charging with gas, the delivery pump, with the column isolated from the vacuum equipment, is set to the required charging pressure, and the gas is allowed to diffuse into the continuously renewed film of liquid. At the end of the charging process, the liquid is collected in the pump chamber, where it is sealed off from the other portions of the apparatus. The subsequent degassing of the liquid directly gives the quantity of dissolved gas. The breakdown vessel (7) is located in a circuit parallel to that of the delivery system and can be filled with gas-free or gas-charged liquid by opening cocks (8) and (9).

The paraffin oil employed in the tests had a molecular weight of 357, a density of 0·842 gm/cm³ at 20°C, a refractive index at 20°C of 1·4597, and contained 0·1% by weight aromatics, about 15% naphthenes, and about 85% paraffins. The gases used were nitrogen, hydrogen, carbon dioxide, and a propane-butane mixture (3:2 by volume), and were taken from the usual commercial steel cylinders and first subjected to thorough drying. A quantity of 300 cc was used for all tests, each of which was conducted at 20°C. Charging pressures were between 0·001 and 770 mm Hg. The electrode spacing was 2 mm, adjustable with an accuracy of 0·04 mm.

Test Results

The results of gas-solubility measurements at various pressures are given in the following table :—

Pressure [mm Hg]	Solubilities [cc/gm]			
	Nitrogen	Oxygen	Carbon Dioxide	Propane-Butane
180	—	—	—	3·0
200	0·023	0·038	0·239	—
300	0·034	—	—	—
360	—	—	—	5·6
400	—	0·079	0·442	—
500	0·054	—	—	7·9
600	—	0·117	0·645	—
700	0·076	—	—	10·9
750	—	—	0·832	—
770	0·084	0·151	—	—

An examination of these results shows that Henry's law (dissolved mass is proportional to pressure) is obeyed over the entire range. The absorption isothermals are straight lines with a slope of about 45 deg.

The test programme provided for comparative measurements of electrical breakdown strength for oils containing various gases and for degassed oils, the latter being brought to the required pressures by hydraulic loading. In this connection, it was also decided to investigate whether appreciable quantities of gas could diffuse into the oil during the periods required for pressure equalization. From the known values of diffusion coefficients this was not expected, and the tests confirmed this point. Even after three hours, with an oil surface area of 70 cm² at a pressure of 750 mm Hg, only 2% of the amount of gas corresponding to solution equilibrium was dissolved. For a surface area of 2 cm² under otherwise similar conditions, the quantity was too small to be measured.

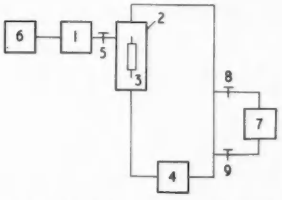


Fig. 1. Schematic layout of test apparatus.

In the investigation of electrical breakdown strength, each test programme for a given gas consisted of at least two series of measurements. In the first, the oil was charged with the amount of gas corresponding to the external pressure ; in the second, the degassed oil was brought into contact with the test gas at various pressures by opening cock (8) (Fig. 1) for a brief period only, so as to balance any hydraulic pressure in the breakdown cell.

The main results of these tests are given in the table below, in which q = the quantity of gas dissolved [cc/gm], and E_d = the breakdown strength (mean of six breakdowns) [kV/cm]. The values in brackets are for degassed oil in brief contact with the gas.

Charging pressure mm Hg]	Nitrogen		Oxygen		Carbon Dioxide		Propane-Butane	
	q	E_d	q	E_d	q	E_d	q	E_d
0·002	—	—	—	179	—	—	—	—
0·003	—	(175)	—	—	—	—	—	—
0·006	—	—	—	—	—	—	—	185
0·008	—	180	—	—	—	—	—	—
0·020	—	—	—	—	—	181	—	—
100	0·011	193(193)	—	—	—	—	—	—
150	—	—	—	(200)	—	—	—	—
180	—	—	—	—	—	—	3·0	188
200	0·023	209(212)	0·038	204	—	—	—	(221)
250	—	—	—	—	0·28	218	—	—
350	—	—	—	(235)	—	—	—	—
360	—	—	—	—	—	—	5·6	197
400	0·044	231(241)	0·079	242	—	—	—	(239)
450	—	—	—	—	0·50	252	—	—
600	—	—	0·117	264	—	—	9·5	212(254)
738	—	—	—	—	0·81	271	—	—
750	0·081	268	0·147	272(278)	—	—	10·9	221(268)
770	—	(287)	—	—	—	—	—	—

In the tests on oil samples charged with nitrogen or oxygen, it was conceivable that, with six breakdowns in each instance, the oil might react with the gas, thereby affecting the results. As a matter of fact, on opening up the apparatus, the typical odour of amines or aldehydes was noticeable in some cases, but the infra-red spectra of the oil and gas showed no foreign bands at this point ; therefore, the proportion of secondary products was below the sensitivity threshold of 0·1 to 0·5%. The electrical strengths of an oil sample degassed again after the test series were also of the same order of magnitude noted for fresh oil samples. The evaluation of scatter yielded comparatively low values of standard deviation (between 1 and 5%). As will be shown later, electrical breakdown strengths decreased noticeably only with solutions containing more than 1% of alcohol by weight.

In the tests on gas-free samples, no marked development of gas was observed, even during breakdown. There was also no gas production with the gas-charged oils, before breakdown, as long as the dissolved quantity of gas corresponded to the equilibrium conditions determined by the external pressure. During breakdown, however, gas bubbles were formed, which dissolved again in the time before the next test was effected, i.e., within five minutes. However, when the quantity of gas dissolved was greater than the amount corresponding to external pressure, on application of the voltage a considerable quantity of gas was generated, even before breakdown ; the electric strength in such cases decreased appreciably.

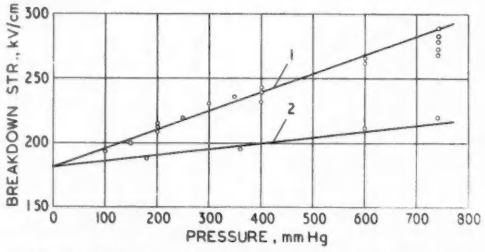


Fig. 2. Graph showing electrical breakdown strength as a function of pressure.
Curve (1) : Oxygen, nitrogen, and carbon dioxide.
Curve (2) : Propane-butane mixture.

In order to obtain some measured values for this effect, the gas pressure was reduced to 1 mm Hg, from two series of oil samples charged with oxygen at 200 and 750 mm Hg respectively. No gas appeared during this pumping process. The values of electrical breakdown strength subsequently obtained for these samples were respectively 33% and 59% lower than the expected values for equilibrium charging at 1 mm Hg, or 44% and 75% lower than at 200 or 750 mm Hg external pressure.

The pressure dependence of breakdown strength was determined for all the gases previously mentioned; the results give straight-line relationships, as shown in Fig. 2.

These values are in agreement with the view previously expressed[1] that the electrical breakdown strength of a hydrocarbon under equilibrium charging does not depend on the type and quantity of gas involved, but on the pressure chosen. The equation for electrical breakdown strength E_d [kV/cm] in terms of pressure p[mm Hg] can be expressed as

$$E_d = 181 + 0{\cdot}15p \quad .. \quad .. \quad .. \quad (2)$$

The somewhat lower values of the test points in Fig. 2 at atmospheric pressure are not considered to be representative and are attributed to an increase in possibilities of errors at the beginning of the preliminary degassing or to insufficient pressure equalization. The results obtained by Inge and Walther[4], according to which electrical breakdown strength would not be a linear function of pressure at the lower pressures, can only be explained by suggesting that the samples used by these investigators at low pressures were probably not degassed down to solution equilibrium.

The constants in eq. (2) are of the order of magnitude of the measured values indicated by Sorge and Friese in their investigation. In this connection, Nikuradse[5] expressed the view that breakdown at normal pressure can be regarded purely as a result of ionization. According to Rummel[6], the ionization energy [eV] of non-excited molecules of nitrogen is 15·5, of oxygen 12·5, of water 12·6, of carbon monoxide 13·6, of carbon dioxide 17·7, of propane 11·3, and of ethyl alcohol 10·8. Comparison of these ionization energies would necessarily lead to the conclusion that air or carbon monoxide and carbon dioxide, which are more difficult to ionize than hydrocarbons, should contribute to a lesser extent to breakdown at pressures below 1 atm than the vapour of low-molecule oil constituents. From this point of view, dissolved hydrocarbon gases should have a greater influence on the electrical breakdown field than the other gases investigated. To ascertain whether this was, in fact, true, in a preliminary test a propane-butane mixture was dissolved in the paraffin oil. The breakdown strength in this case was again a linear function of pressure, but the numerical values were below those from which eq. (2) was derived. At atmospheric pressure, the breakdown field was about 20% lower. It is planned to extend test to other saturated and unsaturated hydrocarbon gases.

In order to determine whether the composition of the liquid phase could also have a marked influence on results, two series of tests were made with paraffin-oil samples in which 1% and 3% by weight of dodecyl alcohol were dissolved. The 1% addition produced no alteration in breakdown strength, but the 3% addition produced a marked change with an appreciable deterioration of the values of electrical breakdown strength.

Conclusions

Tests on various hydrocarbons with similar molecular weights and vapour pressures indicate that the electrical breakdown field is proportional to the density of the hydrocarbon at atmospheric pressure. However, with decreasing pressures the change is greater than that

(*Concluded on page 365*)

Carbon-Brush Friction and Chatter

By E. I. SHOBERT II. (From *Power Apparatus and Systems* (*A.I.E.E.*), No. 30, June 1957, pp. 268–275, 9 illustrations.)

As described in this paper, a practical method of determining the conditions influencing brush vibration has been developed and can be used to produce optimum brush-holder designs. In addition, it is shown that the theory of stick-slip motion must be reconsidered, since this mode of motion does not require a variation of the coefficient of friction with velocity, as has been proposed.

FROM the standpoint of designers and operators of electrical machinery, carbon-brush friction and chatter are important problems. Frictional heat causes additions to the maximum design values of temperature permitted by construction materials, and chatter can, in particular circumstances, destroy the brushes on a machine which otherwise would be satisfactory. The information concerning electrical machines on these two points has been very inconsistent.

To study the problem of chatter, a brush-holder arrangement was made which permitted the brush angle to be changed while the machine was running. Brush chatter was established, and the conditions for its maintenance and continuation investigated. Before discussing the details of the experiments run on this machine, however, it should be pointed out that simple measurements of the coefficients of friction of various brush grades, made by measuring power losses on slip-rings, do not correlate with observations of brush chatter. Admittedly, for very high values of coefficients of friction, chatter would usually appear, and with very low values of friction there would usually be no chatter, but there have always been exceptions at both ends of the ranges, and the data from intermediate materials which comprise most applicable brush grades cannot be correlated.

The coefficient of friction μ is defined by the relation

$$\mu = F/P \quad .. \quad .. \quad .. \quad (1)$$

where F is the friction force on the slider, tangential to the sliding surface, and P is the normal force holding the sliding surfaces together. As Holm[1] and Bowden[2] have shown, the friction force F may be written

$$F = \psi S \quad .. \quad .. \quad .. \quad (2)$$

where S is the true contact surface and ψ is a shearing force per unit area in this surface. However, from contact-hardness measurements as defined by Holm, Holm, and Shobert[3]

$$P = \xi H S \quad .. \quad .. \quad .. \quad (3)$$

where H is the contact hardness of the softer member of the sliding combination, measured as a force per unit area which the surface will support, and ξ is a coefficient which is usually near unity for new contacts with surfaces which are not completely seated in. The factor ξ decreases when the contact surfaces are worn in by sliding and may easily attain values of about 0·3 to 0·2. Combining eqs. (1), (2), and (3) gives

$$\mu = \psi/H\xi \quad .. \quad .. \quad .. \quad (4)$$

The shearing strength ψ is the major variable in eq. (4). In hydrodynamic lubrication, where the surfaces are supported by a film of liquid, ψ is very small. In the case of carbon brushes on copper rings and commutators, the primary concern is with boundary and solid lubrication. An adhesive layer of water prevents seizure when available.[4,5] The graphite film also prevents seizure when it can be effective. The effectiveness of the graphite film disappears when the moisture layer disappears, as evidenced by the high-altitude wear problem discussed by Savage[4] and Elsey[6].

On the other hand, carbon-brush chatter takes place under ordinary atmospheric conditions, when the moisture and graphite lubrication are still effective. Therefore, some cause other than dryness must be looked for. The coefficient of friction μ of carbon brushes on copper is known to depend on temperature, so that, at about 30°C, its value may be about 0·25, dropping to about 0·1 at 100°C and then rising to 0·15 at 200°C. This is partly responsible for brush chatter under light-load running conditions, since machine temperatures are low at low currents. It has been noted in many cases, however, that chatter does not start until some time after the machine has cooled. Under light-load running, ξ in eq. (4) will decrease, since brush and ring wear rates are low and the surfaces become smooth.

The above factors give no clue to the explanation of the chatter effects. The mechanical analyses made to date of the brush-chatter problem do not permit a suitable comparison of observations on different machines to be made.

A simple experiment with a piece of chalk can be used to demonstrate the modes of brush vibration. By holding the chalk against a blackboard and at a leading angle to the motion, a high-pitched squeal can be developed, leaving a continuous line of chalk on the board. This is a transverse vibration, corresponding to the vibration of a bar with free ends. That it is the question of transverse oscillations is evident, since the frequency is inversely proportional to the square of the length of the chalk. The equation for the movement is similar[7] to eq. (6), except that $a^2/12$ must be replaced by $r^2/4$, where r is the radius of the chalk.

By holding the chalk near the end away from the board and sliding it at a leading angle, the chalk vibrates, or actually jumps, at a much lower frequency, and the line is a series of discrete points separated by some distance. The frequency in this case depends on the elasticity of the fingers and the force applied. This type of motion can occur in brushes and is noted when the high-pitched squeal gives way to a rattle or chatter. As can be seen in the following, carbon-brush chatter is the result of the combination of both types of vibration, in which the high-pitched squeal is modulated by the lower frequency characteristic of the brush support. Both of these modes of vibration, excited by friction, were considered possible.

APPARATUS FOR INVESTIGATION OF BRUSH CHATTER

The set-up for investigation of brush chatter is shown schematically in Fig. 1. The holder can be rotated around an axis parallel to the axis of the copper drum. The limits of this rotation are shown in Fig. 1 for this particular set-up. Brushes were cut and tested leading, as shown, and also trailing. Flat-face brushes and brushes with a line contact in the centre of the brush were also tested. The copper ring, 10 in. in diameter, rotates at 1800 rpm. The angle which the brush makes with the surface of the

ring can be varied by moving a lever on the front of the holder. A scale indicates the angle.

After considerable investigations into the means required to develop chatter noise, it was found desirable to use the brush design shown in Fig. 1, so that the point of application of the friction force to the brush could be defined. Chatter noise can be developed by ordinary brushes on the machine but, unless the location of the friction contact can be defined, no consistent experimental record is possible.

Chatter experiments on the machine and on d.c. generators are reported in the following sections. In addition, sound motion pictures in colour were taken of some of the experiments.

Measurement of Vibration Frequencies

The outstanding characteristic of brush chatter is a high-pitched squeal, which may degenerate in time to a chatter with the squeal in the background. It was noticed with the machine that, using a brush with a square face, when an audible sound first appeared, it was a pure tone, like a whistle, which might be modulated in intensity but which had a well-defined frequency. The sound was picked up with a dynamic microphone and photographed on the screen of a cathode-ray oscillograph, the sound frequency being 3100 cps. It was found that the resulting sound frequency could be varied from about 2500 to about 4500 cps by changing the brush angle, by touching the brush with the fingers, and, in general, by changing the forces between the brush and the holder. On the other hand, under a particular set of conditions, the frequency remained reasonably constant, i.e., within two musical tones. It should also be noted that, whether the brush used was a rectangular piece of carbon with a square face or of the shape shown in Fig. 1, the same frequency range was developed.

The brush was run on the leading edge with the line *OA* in Fig. 1 in the chatter range, so that the point of application of the friction force was defined. The same brush was then removed from the machine, clamped at one end in a vice, and a thin layer of resin paint applied to the other end. When this had dried suitably, it was stroked with a cello bow, when it was found to vibrate transversely with the tone and frequency, the brush vibration frequency being 1750 cps.

This mode of vibration is that of a bar clamped at one end, and the frequency of this transverse vibration is given by the following equation[8]

$$\nu_n = \frac{\pi}{2l^2}\sqrt{\frac{Ea^2}{12\rho}}\,\beta_n^2 \quad .. \quad .. \quad (5)$$

where ν_1 is the fundamental frequency, l is the free length of the bar, ρ is the density, E is Young's modulus of the brush material, a is the thickness of the brush, and $\beta_1=0{\cdot}597$, $\beta_2=1{\cdot}494$, $\beta_3=2{\cdot}500$, etc. For the brush in question, $l=4{\cdot}45$ cm, $a=1{\cdot}27$ cm, and $\rho=1{\cdot}6$ gm/cm^3. Using the value of ν, as measured, i.e., 1750 cps, and $\beta_1=0{\cdot}597$, $E = 0{\cdot}56 \times 10^{11}$ dynes/cm^2, which is in very close agreement with values of Young's modulus measured statically.

It is now necessary to account for the difference between 1750 cps measured by vibrating the brush held in the vice and excited with the cello bow, and the 3100 cps measured with the same brush in the brush-holder on the machine.

The frequency of transverse vibration[7] of a bar either clamped at both ends or free at both ends is

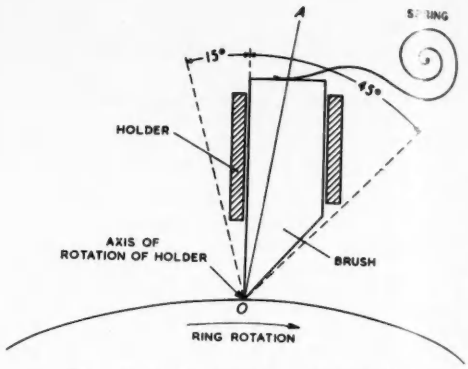


Fig. 1. Schematic diagram of special brush-holder.

$$\nu_n' = \frac{\pi}{2l^2}\sqrt{\frac{Ea_2}{12\rho}}\,\beta_n'^2 \quad .. \quad .. \quad (6)$$

where $\beta_1' = 1{\cdot}506$, $\beta_2' = 2{\cdot}4997$, $\beta_n' \cong n+1/2$ for $n>2$. Thus, $\nu_1' = 6{\cdot}3\nu_1$, while a ratio of about two is indicated.

The frequency of longitudinal vibration of a bar clamped at one end is

$$\nu_n'' = \frac{(n-1/2)}{2l}\sqrt{\frac{E}{\rho}} \quad .. \quad .. \quad (7)$$

Neglecting a small correction due to Poisson's ratio, $\nu_1'' = 11{\cdot}4\nu_1$.

Thus, the lowest frequencies which could be present from these other possible modes of vibration of the brush are far above the measured frequency, and these modes are therefore eliminated from further discussion. Vibration of the holder and spring has been eliminated by demonstrating that frequency changes very little when the spring and holder are damped by manual pressure.

On the other hand, if the effective length of the brush is decreased to 0·75 l, the frequency increases from 1750 to 3100. It therefore appears that the resultant force between the brush-holder and the brush can act at different positions on the brush and thus change its effective length. This explains the range of frequencies observed on the test machine.

It is concluded that the brush is vibrating transversely in the manner of a bar clamped at one end, and that the effective length is not well defined, because of the inconsistent damping of the brush-holder. Other modes of vibration may be present in different circumstances but, as will be seen later, they do not influence the final conclusions.

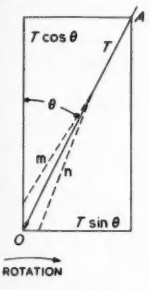
Variation of Brush Chatter with Brush-Holder Angle

In the preliminary investigations on the machine it was found that, after the sound had developed, any change in brush angle would decrease the intensity of the sound, but that, if the brush were left standing at the new angle for a few minutes, the sound intensity would again increase. If the angle was changed, a new surface on the brush must be developed as the factor ξ in eq. (4) decreased, until the tone attained its final intensity. It was therefore necessary to let the brush run in at any given angle for a period of 20 min before a decision could be made concerning noise. In some cases it was also found

that at certain angles the brush would not chatter unless its upper end was pushed away from the walls of the holder with the finger-tips.

This procedure was used to obtain a series of data on plain electrographite and treated electrographitic brushes. A whistle or chatter of any type was taken as the sign that chatter could take place at that angle. Moving the brush in the holder by hand decreased the pressure of the holder. The angle of the holder was changed in steps of 2½ deg., and the brush-angle range giving chatter was measured for various brush materials. Similar data were taken with the brush reversed in the holder, i.e., with the brush riding on its heel, instead of on its toe, as shown in Fig. 1. The angle and range of chatter is the same when referred to line OA in Fig. 1.

The basic conclusion which can be drawn is that brush treatments which are known to reduce the average friction do not necessarily change the conditions under which brushes may chatter. On the other hand, since the analysis indicates that the chattering brushes are vibrating transversely, some general conclusions can be reached concerning friction in brushes from the following analysis.



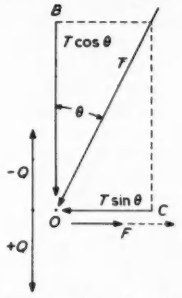


Fig. 2 (left). Diagram of transverse vibration of brush.
Fig. 3 (right). Diagram showing relation between brush spring force and elastic forces during vibration.

It can be seen from the foregoing that the chatter is a dynamic process with a certain eigen frequency, and now its relation to the friction between brush and ring must be discussed. In Fig. 2, as in Fig 1, AO is the line between point A, where the spring exerts the force T against the brush and point O of the brush-ring contact. The lower part of the brush vibrates between positions m and n (their distance from AO is shown very exaggerated). Consider the movement, beginning at a time when the brush approaches position m. Here, the brush is slightly lifted, possibly separated from the ring in certain circumstances; in any case, it presses against the ring with no force or with a smaller force $T\cos\theta - Q$, as shown in Fig. 3, than the vertical component of T. The rest of this component is occupied by retarding the vibration motion of the brush, which becomes nil in position m. Then, the elastic forces, together with this component, accelerate the lower part of the brush to position n. When arriving at this position the brush exerts a greater force ($T\cos\theta + Q$ in Fig. 3) against the drum, and the friction force is correspondingly great. At this point the friction force gives an impulse to the brush, which balances the energy losses, so that the vibration can be sustained. Thereafter, elastic forces drive the brush back towards position m, and the process is repeated. It is evident that it is essential for maintenance of the vibration that, at the moment of the highest friction force, this friction force should act in the direction of increasing the deviation from line AO, which happens only when the brush slides with a leading angle. This explains why chattering does not appear when the line OA is to the left of the vertical shown in Fig. 1.

Nevertheless, an explanation is needed for the fact that chatter stops after a certain maximum value of angle θ. Consider the conditions for the lower end of the brush to obtain horizontal impulses in the direction of the drum movement shortly before position n (Fig. 2). To sustain the vibration, it is essential that Q should have its maximum value shortly before position n, so that $T\cos\theta + Q$ is decreasing at n. At such a moment the mass forces of the brush end are partly counteracted by the elasticity, but they nevertheless also exert a pressure force Q against the drum, which adds to component $T\cos\theta$ of the spring force. The reaction from the holder which is perpendicular to the brush side has a negligible influence on the pressure between brush and ring, and essentially keeps a certain cross-section of the brush in a stationary position. Thus, the horizontal impulse on the brush is constituted by the difference between the friction force F and the retarding component $T\sin\theta$. Since the friction force is $F=\mu\,(T\cos\theta + Q)$, the condition for the impulse considered to be accelerating is

$$\mu(T\cos\theta + Q) \geq T\sin\theta \qquad .. \quad .. \quad (8)$$

$$\text{or } \mu > \frac{\tan\theta}{1+(Q/T\cos\theta)}$$

Consequently, oscillations will not occur if

$$\tan\theta \geq \mu\,[1 + (Q/T\cos\theta)] \; .. \qquad .. \quad (9)$$

Eq. (9) explains why an upper limit of θ exists for the chatter range.

It is proved in the following that eq. (9) is satisfied by the average friction coefficient μ measured between the brush and the drum. No hypothesis of a dependence of μ on sliding velocity v seems to be necessary to explain brush chatter. This is contrary to the hypothesis of Bowden[9] that " slip-stick " motion is caused by the dependence of the coefficient of friction μ on the relative velocity v between the slider and the drum. This point may have general application to all such problems of friction-excited vibrations. The magnitude of Q is estimated in the following sections from the electrical tests.

Variation of Frequency with Ring Speed and with Brush Spring Force

The intensity or volume generated by a stringed instrument depends on bowing pressure and velocity, but frequency changes only slightly with variations in pressure and velocity. If a similar effect is dealt with, the results should be similar on this machine. Both of these effects have been demonstrated in the sound film already mentioned. When spring force is varied, frequency remains constant within about one musical tone. When speed is varied by letting the machine coast to a stop, frequency remains constant to within one-eighth of a musical tone, with a slight decrease in intensity.

Effect of Current on Brush Vibration

In electrical machines in practice, most of the difficulties due to brush chatter occur under conditions of no-load or light-load running. The average value of the coefficient of friction increases at low temperatures, as noted previously, and the factor ξ in eq. (4) will decrease when current is low, because the brushes will seat into a smoother surface. Some investigators have believed that electric current alone is responsible for these differences, but experiments on this machine have disproved this.

This experiment is also shown in the sound film. The brush is set chattering with no current. Current is then turned on and off several times, with no change in the sound from the brushes. This current is 30 A through the thin edge of the brush shown in Fig. 1, so that the current densities are of the order of 400 A/cm² of the apparent surface ; however, lower current densities have the same effect. This compares with normal current densities of 12 A/cm² for electrographite brushes.

It may thus be concluded that current through the contact surface has no major effect on friction and that the results noted on practical machines are caused by temperature and wearing-in conditions, which are, of course, partly determined by current, but which must be developed after running for a period of time.

Effect of Changing the Mass of the System

An experiment to change the mass of the system was made to be certain that the mathematical analysis of chatter frequency was correctly based. A piece of copper, weighing about one-third the weight of the brush, was placed between the brush spring and the brush. As noted in the sound film, the frequency decreased about one tone. This is within the range of frequencies that can be developed without the added mass, so that the conclusion can be reached that the spring was not involved in this particular dynamic system. The same effect can also be heard in the sound film when the brush is moved by hand and the brush pressure changed by pushing on the top of the spring.

Voltage Drop of a Chattering Brush

Oscillograms were made of the voltage drop of the brushes on the machine under three different conditions of noise or chatter, i.e., (1) operation with no brush chatter or vibration, (2) operation with the sound from the brush very nearly that of a pure tone, and (3) operation with the chatter or rattle developed when condition (2) is kept in operation for some time.

Under condition (2), voltage drop was found to be influenced to some extent by brush vibration, but the effect was small and would probably be harmless, if it remained constant. This is a rather surprising effect, as it has always been believed that any vibration can drastically influence voltage drop. This, however, has been shown to be untrue.

Under condition (3), when the sound changes from a tone to a rattle or chatter, voltage drop of the brushes is drastically affected. This is the condition which causes difficulties in electrical machines and which can cause destruction of the brushes and severe damage to the commutator. Naturally, in a machine, it is merely an academic question whether condition (2) or condition (3) is present, as it has been found that, in practically all tests, condition (2) becomes condition (3) if allowed to continue for any appreciable length of time.

Comparison of the voltage-drop data obtained under conditions (1), (2), and (3) permits a correlation with the estimate of the variation Q in pressure, as calculated from eq. (9). By comparing the peak values of voltage drop from the oscillograms made under conditions (1) and (2), it was found that the values obtained for condition (2) were about 20% higher than those for condition (1) ; with the same current flowing, this means that the contact resistance is 20% higher. The contact resistance in sliding contacts is inversely proportional to a linear dimension of the area. In fact, it can be shown that contact resistance R is proportional to $\rho/\sqrt{S}$ and to $\rho/\sqrt{P}$. Thus, a change of 20% in the contact resistance can be expected to be the result of a variation of about 40%, i.e., $\pm$ 20%, in the normal force $P = T\cos\theta$. In eq. (9), $Q/T\cos\theta$ is about 0·2. From the data obtained in these tests, the maximum value of θ was 15 deg., so that, from eq. (9)

$$\mu = \tan 15°/1{\cdot}2 = 0{\cdot}22$$

Measured values of μ under the conditions of these experiments range from 0·20 to 0·25, so that the measured variation in contact resistance supports the arguments of eq. (9) that the friction force F varies because of the variation in the contact force rather than because of variations in the coefficient of friction.

In the case of chatter under condition (3), the electrical circuit is almost interrupted, and then the value of $Q/T\cos\theta$ approaches unity. Under these conditions, the power-input measurements of the coefficient of friction have been observed to decrease at the instant the tone changes to a chatter. These measurements have a different physical meaning, since the brush is not touching the ring or drum all the time.

Application to Practical Machines

In practical machines, advantage is taken in the design of the brush-holders and springs to minimize the possibility of brush chatter by using top bevels on the brushes to hold them against one side of the holder, and by using either trailing or reaction holders on machines which always run in one direction. However, the designs of many large machines still permit the possibility of brush chatter in special circumstances such as brush-holder and brush wear, commutator refinishing, etc. No analysis previously available has given limits for instability, and permanent solutions have not always been applied to the problems at hand. The method described in this paper has been applied by several machine manufacturers to their brush problems with success.

One problem in applying this analysis to practical machines is that the point of application of the friction force is not always well defined. The brush usually wears to a somewhat larger radius than the commutator, and the friction force may be applied to the brush at different points over its thickness. To prove this theory on practical machines it would be necessary to determine and then vary the point of application of the friction force, and finally listen for chatter.

(*Concluded on page 366*)

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ENGINEERING, MARINE, WELDING, AND NUCLEAR ENERGY EXHIBITION

Exhibits by **Firth Brown,** of Sheffield, have been selected to present a range of forgings typical of their heavy forge department, forged-steel rolls, steel castings, steel bars, and drop forgings, totalling about 120 tons. Of these, an interesting item will be a 120-MW steam-turbine rotor for the Staythorpe "B" power station, comprising a forged shaft in 3% Cr-Mo steel in the rough-machined, smooth-bored condition, weighing 31½ tons and having an overall length of 18 ft 8 in. and a main diameter of 4 ft 6 in. This shaft, which is being made for Metropolitan-Vickers Electrical Co. Ltd., is typical of many such shafts being constructed for the electrical industry.

Another Firth Brown exhibit will be a hollow forged steam drum of 33 ft in length and 6 ft 2 in. o.d., weighing 50 tons. This drum, which is one of eight projected by Mitchell Engineering Ltd., of Peterborough, for the State Electricity Commission at Victoria, Australia, is designed for an internal pressure of 1550 psi and will evaporate 235,000 lb per hour.

Other Firth Brown exhibits will include a main gear-wheel rim forging, 13 ft 2 in. in diameter and weighing 10 tons, for the propulsion machinery of a 32,500-ton tanker; forged-steel flanges for CO_2 ductwork and bellows for a nuclear power plant; a die block in Ni-Cr-Mo steel, weighing 175 lb and produced on a 12,000-ton hydraulic press; two forged-steel rolls, one as-forged, and the other with a mirror finish, both rotating vertically on a motorized unit; a cast-steel crank-web and other castings; a range of alloy-steel bars; models of steel forgings; and a range of drop forgings by Firth-Derihon Stampings Ltd.

Among a comprehensive range of equipment, including a model of a 625-bhp diesel-hydraulic locomotive constructed for the Indian Railways (Western), the **North British Locomotive Company Limited,** of Glasgow, will exhibit representative examples of their range of N.B.L.-M.A.N. diesel engines, which cover a range of power outputs from 90 to 1100 bhp. The normally aspirated W6V 17·5/22A engine, with a power rating of 225 bhp at 1100 rpm continuous, is illustrated in Fig. 1.

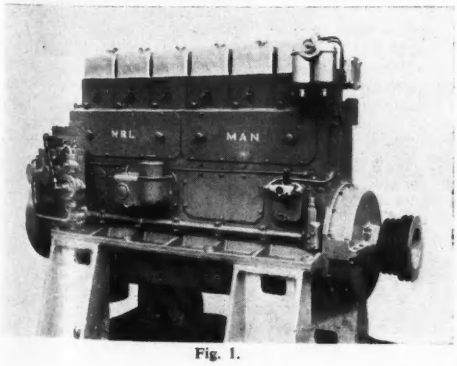

Fig. 1.

The L12V.18/21 supercharged V12 engine, also to be exhibited, is of particular interest. Weighing only about 4¼ tons, this engine, operating on a 12-hr rating at 1500 rpm, delivers 1100 hp; consequently, its power/weight ratio is very high (a conventional in-line engine requires a weight of just over 7 tons to produce 1000 hp), and makes it particularly useful to designers of diesel locomotives and high-speed water craft.

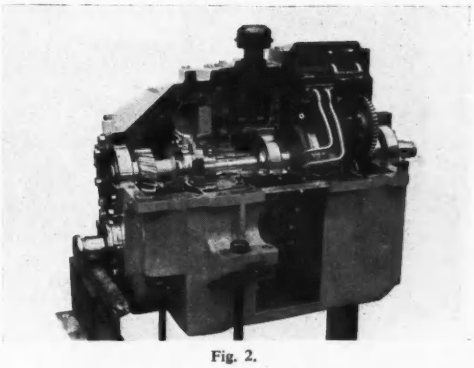

Fig. 2.

Other exhibits from the North British Locomotive Company will include Voith/North British hydraulic transmissions, which are available in capacities ranging from 75 to 1036 hp input. Of these, two examples, the type L22m for a 100-hp input and the L37zv for a 789-hp input will be exhibited. A sectioned view of a type L22 fully automatic hydraulic transmission is illustrated in Fig. 2. Primarily designed for rail-traction applications, these transmissions reduce driving merely to operation of the engine throttle and brake. The transmission is fully automatic, as it incorporates a governor which is sensitive only to road speed and, although a locomotive may be overloaded to the point of stalling and beyond, the engine cannot be stalled, as the transmission will not absorb more power at its input shaft than its design figure. Simplicity and robustness are inherent features, and maintenance is extremely low, as all parts are continuously lubricated and run in ball or roller bearings.

In addition to several new products to be exhibited for the first time by **The Brush Group,** a most comprehensive range of engines, from 6 to 3096 bhp, will be shown by this organization. Among these new products will be a range of gas turbines specifically for use with single or multiple free-piston gasifiers. These units, which are produced by the **Brush Electrical Engineering Company Limited,** of Loughborough, have a present range from 1000 to 10,000 hp. To ensure that the greatest amount of heat is converted to useful work from the relatively low conditions, i.e., about 4 atm and 450°C, Brush gas turbines are multistage axial-flow units with reaction-type free-vortex blading. In addition, parasitic

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losses are reduced by adopting a volute form for the intake casing, and a diffuser is fitted at the blade-exit annulus. Other exhibits by this company will include a turbocharger for diesel engines, with a 2:1 pressure ratio and a rating of 4000 cfm; a marine-type salient-pole alternator, 250-V, 3-phase, 50-cps, 500-rpm, 280-kW, 350-kVA; an electronic high-speed precision tachometer Mk.2, with an accuracy of ± 1 rpm up to 18,000 rpm and ± 10 rpm up to 180,000 rpm on the $\times 10$ range; and a portable vibration indicator for investigation of a wide variety of vibration problems.

Another new exhibit will be the National GS.34 free-piston gasifier, manufactured under licence from Alan Muntz & Company Limited, Pescara, and S.E.P. by the **National Gas & Oil Engine Company Limited,** of Ashton-under-Lyne. This unit, which is claimed to be one of the first British-built models of its power, has a continuous rating of 1232 ghp, or about 1000 shp for marine propulsion duties. The stationary design develops 1250 ghp, which is equivalent to about 720 kW as a continuous rating. Other exhibits by this company will include an example of the National NM-series engines, produced in 6- and 8-cylinder designs with an overall power range from 164 bhp at 1000 rpm to 533 bhp at 1500 rpm or 660 bhp at 1800 rpm. The horizontal or "flat" NM engine, of which the 6-cylinder mechanically blown design will be exhibited, has been developed especially for underfloor railcar and shunter applications. The range, however, as a whole, is eminently suitable for large excavators, drill rigs, and marine propulsion, in addition to rail-traction duties. Also to be exhibited by the National Gas & Oil Engine Company will be a working model of the engine room of the T.S.M.V. "Princess of Vancouver", comprising four National B4AUM7 geared diesel engines with a total service power of 5040 shp, and a National F4AUM6 marine propulsion engine which, driving through a Hindmarch/M.W.D. 2:1 reverse-reduction gearbox and fitted with Chadburn "Synchrostep" control, permits bridge control of the engine.

A new exhibit from **J. & H. McLaren Limited,** of Leeds, will be an example of the new LE range of high-speed lightweight diesel engines for universal use, and will take the form of the Petter McLaren LE6 marine propulsion unit, which is a 6-cylinder, vertical, water-cooled engine developing 135 shp at 1500 rpm, with a "self-change" oil-operated reverse and a 3:1 reduction gearbox. This engine is not only robust and of advanced design and performance, with a high power/weight ratio and compact dimensions, but has exceptionally good accessibility for servicing and maintenance. Other McLaren exhibits will include a Petter McLaren PD4M marine propulsion diesel engine. This 4-cylinder, vertical, in-line engine develops through a Parsons "F"-type reverse and a 2:1 reduction gearbox 29·5 shp at 600 rpm to 43 shp at 900 rpm, the engine itself being rated at from 32 to 48 bhp at 1200 to 1800 rpm. In addition, McLaren will exhibit a Petter McLaren marine auxiliary generator set comprising an LE4 4-cylinder water-cooled diesel engine, developing 120 bhp at 1500 rpm, and a Brush 220-V, 60-kW flange-mounted d.c. generator, the whole set being complete with heat-exchanger equipment.

The largest engine in the Brush Group exhibits will be shown by **Mirrless, Bickerton & Day Limited,** of Stockport, and will consist of an example of a Mirrless KVSS12 engine developing 3096 hp at 428 rpm. These "K"-type engines are available in power ranges from 192 to 4128 bhp at speeds up to 450 rpm and in sizes from three to sixteen cylinders. The KVSS12 and KVSS16 turbocharged versions with air coolers are stated to be the most compact power units of their type. The "K"-type engine has a bore of 15 in. and a stroke of 18 in. and has a multiplicity of applications, ranging from power stations to marine duties.

In addition to two air-cooled marine propulsion units and one water-cooled marine auxiliary, **Petters Limited,** of Staines, another member of The Brush Group, will be showing two engines from an entirely new range of lightweight high-speed air-cooled diesels for automotive, industrial, or agricultural use. These engines are the PC2 twin-cylinder diesel developing 10 bhp at 3000 rpm (exhibited with an automotive-type gearbox), and the PC4, a 4-cylinder engine developing 20 bhp at 3000 rpm. The PC range (in 1 to 4 cylinders) is stated to represent a new attack on the problem of the unfavourable power/weight ratio of the diesel engine, compared with that of the petrol engine. Thus, in the engine of the highest power in this series (all of which have a 12-hr rating at 3000 rpm), this ratio has now been improved to 25 lb/bhp.

One of a new range of diesel engines—the "F" range—consisting of 3-, 4-, and 6-cylinder models from 66 to 160 hp, will be introduced by **Russell Newbery & Co. Ltd.,** of Dagenham, Essex. The new "F" engine to be exhibited will be the 3-cylinder model, which develops from 66 to 80 bhp at 1000 to 1200 rpm. This engine will be shown with the cover doors removed, to demonstrate its special features of accessibility. All engines in the "F" range have a bore of 6 in., a stroke of 7½ in., and a capacity of 205 cu in. per cylinder. Supercharged models are available in the 4- and 6-cylinder models, with a correspondingly increased power output. Thus, while the standard 4-cylinder version develops 57 to 106 bhp in the speed range between 650 and 1200 rpm, the supercharged model develops 106 bhp at 1000 rpm. Similarly, the standard 6-cylinder model develops 74 to 160 bhp between 650 and 1200 rpm, while the supercharged version develops 160 bhp at 1000 rpm.

Other Russell Newbery products to be exhibited will include a diesel marine auxiliary set comprising an R.N. 6-cylinder, 100-bhp, type "E6" engine driving a 50-kW generator and a compressor with a capacity of 47 cfm; a similar set comprising an R.N. 3-cylinder, 27-bhp, type "D3" engine driving a 15-kW generator and a 9½-cfm air compressor; a twin-cylinder, 24-bhp, type "DM2" diesel marine propulsion unit; a "DK1" emergency fire-pump set; and a "Husky" power pump, which is a self-contained pump set with a capacity of 400 gpm used extensively for irrigation purposes.

The marine and electrical engineering interests of the **Associated British Engineering Group** will be represented with products from The Bergius Co., Ltd., British Polar Engines Ltd., The Controllable Pitch Propeller Co. Ltd., Henry Meadows Ltd., H. Widdop & Co., Ltd., and the Free Piston Engine Co. Ltd.

Of these, the **Bergius Co. Ltd.** will feature four engines as the main exhibits, i.e., the E.2 7½-hp Kelvin Ricardo with electric starter, the J.3. 33-hp Kelvin diesel, which is available with hand or electric starting; the P.2. 10-hp Kelvin diesel, with or without electric starting; and the K.4. Series III, 88-hp engine, which is fitted with a Bergius 2:1 water-cooled reduction gear with no fore and aft movement of the propeller shaft, giving a propeller speed of 375 rpm. Another interesting point of this engine is the slow-acting water pump and redesigned water system. Other items to be exhibited by the Bergius Co. Ltd. will be a variety of marine-engine equipment, including a steering-gear stern-tube and propeller.

British Polar Engines Ltd. will show one of their well-known two-cycle, direct-reversing marine propulsion engines, type M48M. This engine will be running under its own power and will demonstrate the simplicity of the two-cycle system used and the engine's capacity for quick and accurate manoeuvring. In service, the engine, which has an output of 1500 bhp at 300 rpm, will operate through a reducing gear and a hydraulic coupling, providing gear protection and producing a good vibratory system. British Polar also intend showing a scale model of their "T"-size engine, rated at 400 bhp per cylinder at 250 rpm.

The Controllable Pitch Propeller Company Ltd. will be showing on the British Polar stand a working scale model of the Lips de Schelde controllable-pitch pro-

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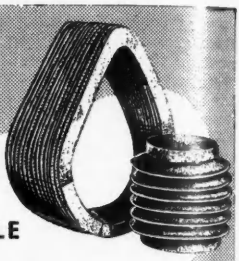

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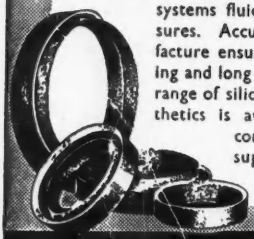

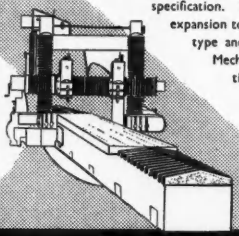

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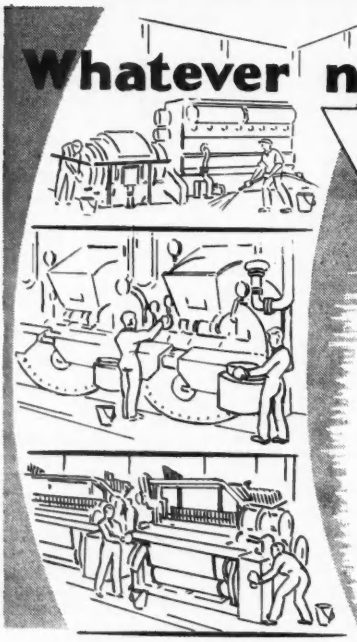

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peller. This propeller is of unique design, with the blades arranged in tandem, so as to secure the smallest possible hub diameter and consequently a very high efficiency over a wide range of pitch settings and engine speeds. Adjustment of the pitch permits absorption of the full engine output at reduced hull speeds ; as such, it is particularly useful for tugs and trawlers. It also provides easy bridge control and is recommended for all cases where manoeuvring problems arise.

Henry Meadows Ltd. will accent their range of generating sets, which have been produced on a rationalized basis with interchangeability of many parts. This rationalization results in a comprehensive range of sets with only three basic frame sizes, and provides for bare power-plants to completely self-contained units, fully or semi-canopied for stationary or trailer-mounted operation. Alternative starting arrangements are available, and there is also a comprehensive selection of optional extras to meet special requirements. Other Meadows exhibits will include a new engine, the 6DJ 500 6-cylinder 100-hp power-plant, the 6 DMS 970 " Nelson " 270-shp marine diesel, the 6 DM 630 " Frobisher " 130-shp marine diesel, and the 4 DM 330 " Porpoise " 90-shp marine diesel.

Exhibits from **H. Widdop & Co. Ltd.** will include a scale model of their GMB6 engine. This engine is a 6-cylinder, pump-scavenged, direct-reversing, two-stroke model with a continuous rating of 726/798 shp at 300/330 rpm. Actual engine components will also be shown, including a piston and connecting-rod assembly. An interesting feature of the Widdop piston is that it is of uniform cross-section, with no gudgeon-pin hole or boss. A cylinder, complete with dry-type liner, will also be exhibited, and will exemplify the robust construction of these separate cylinders and the ease of withdrawal and replacement of the liners. Other exhibits will include a double-acting scavenge-pump piston and a cylinder head. The Widdop cylinder head has no inlet or exhaust valves, and the combustion chamber is free to expand within a large-capacity water jacket, thus eliminating any dangerous heat stresses which might cause cracking of the head.

A model GS.34 free-piston gasifier, with an output of 1250 ghp and a continuous maximum rating of 1000 shp, will be exhibited by the **Free Piston Co. Ltd.**, together with a complete self-contained prototype 200-kW electric generating set comprising a single CS.75 350-shp gasifier coupled to a W. H. Allen & Co. Ltd. 200-kW d.c. marine-type generator through a 7-stage Budworth turbine and reduction gearing. If required, this set can be trailer-mounted.

Examples of the extensive range of " Ficep " range of shearing machines will be featured by **Thos. W. Ward Limited**, of Sheffield, including two " Standard " model universal punching and shearing machines, a range of hand-lever-operated shearing machines, a " Beton " size B.32 portable bar shear, a model CGC size 80 billet and bar shear, and a model CCL 600 alligator shear.

Of these, the model CGC size 80 billet and bar shear has a capacity in cold mild steel up to $3\frac{1}{8}$ in. diameter, $2\frac{3}{4}$ in. square, and $6\frac{3}{8} \times 1\frac{1}{8}$ in. flats, while the " Beton " size B.32 portable bar shear can cut up to $1\frac{1}{4}$-in. mild-steel bars, the blade opening being adjustable for small-size material. The five sizes in this range cover capacities from 1 to $2\frac{3}{4}$ in. bars.

The model CCL 600 alligator shear has 24-in. blades and incorporates an adjustable hold-down, capacities in mild steel being $1\frac{7}{8}$ in. for bars, 7 in. for beams, and $4\frac{11}{16} \times 1$ in. for flats. The CCL range covers four sizes, with capacities up to $3\frac{7}{8}$ in. for bars.

A wide range of electrical and mechanical equipment for marine and industrial applications will be exhibited by The **British Thomson-Houston Co. Ltd.**, of Rugby, including a display of some of the main parts of the actual 1200-hp gas turbine recently removed from the Shell Tanker " Auris " after 20,000 hr running on load. Also to be shown is a model of the new BTH 5500-hp gas turbine and gear drive as it will be installed in the " Auris " to replace the BTH gas turbo-alternator set and three diesel-alternators which form the original propelling machinery.

The part played by BTH in turbo-electric and diesel-electric ship propulsion will be portrayed by means of diagrams and pictures, and these include references to the 90,000-shp turbo-electric equipment for the new liner being built for the P. & O. Company by Harland & Wolff Ltd.

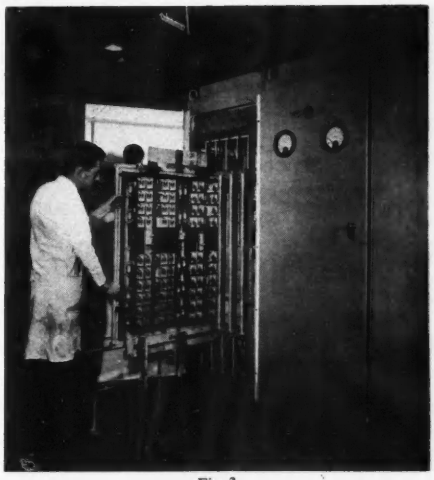

Fig. 3.

BTH heavy plant will be represented by a model of one of the 66,667-kVA water-wheel-driven alternators for Eildon, Australia, and assemblies of six and twelve germanium rectifier cells. A typical BTH germanium power rectifier is illustrated in Fig. 3. The chief items of electronic equipment to be exhibited are a photo-electric relay/" Emotrol " demonstration unit (in operation), a modulated-light photo-electric relay (in operation), a battery-operated leak detector, a flame-control relay I.R. 4, and " Rotabalance " portable electronic balancing equipment, which has two main uses. Thus, it can be used for investigating vibration generally on completed machinery, particularly where it is desired to discriminate between the effects of unbalance and other sources of vibration. It can also be used for investigating vibration due to unbalance conditions which occur for various reasons when machinery is set up on the test bed or in the final location. The " Rotabalance " equipment comprises a measuring amplifier, a dynamometer, a reference generator, and the necessary pick-up units. This equipment is capable of measuring vibration velocities down to 0·005 in. per second, vibration amplitude down to

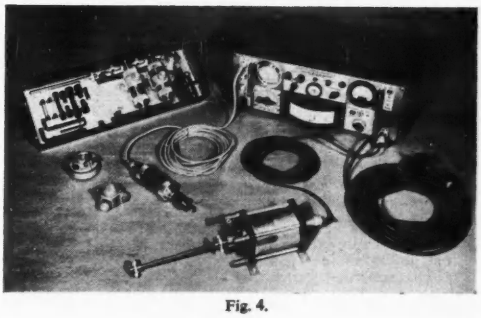

Fig. 4.

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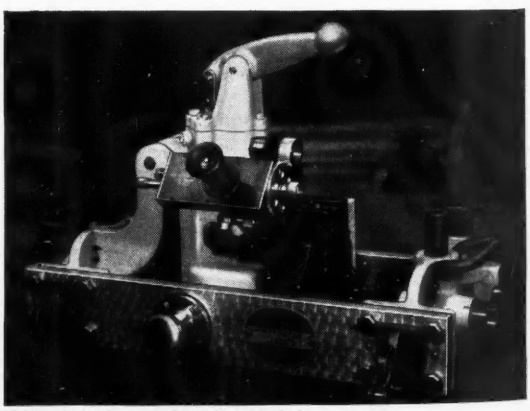

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0·00005 in. (peak-to-peak), and relative phase to an overall accuracy of approximately ± 2 deg. Vibration waveforms can be determined by connecting the voltage output from the measuring amplifier to any convenient portable cathode-ray oscilloscope. Fig. 4 illustrates the basic component parts of the " Rotobalance " equipment and shows (bottom left) one pick-up, (top) the measuring amplifier, and (bottom right) the reference generator with flexible drive.

Representative BTH fractional-horsepower motors, including geared-motor units and also some sectional models, will be displayed, while the company's activities in the nuclear-energy field will be represented by an artist's drawing of the projected Berkeley Power Station which is to be erected on the Severn Estuary, Gloucestershire.

A feature of the exhibits from **Lister Blackstone Marine Limited** will consist of both auxiliary and propulsion versions of the Lister, type LD2, twin-cylinder four-stroke air-cooled marine diesel engine. Of these, the LD2MGR has a power output of 7 bhp (B.S.I. 12-hr rating) at 1800 rpm and weighs just over 4 cwt. It is a most compact unit, the overall length, including reverse and 2:1 reduction gear, being less than 42 in., while the overall width is 22½ in. and the height 33 in. These dimensions include an engine-mounted fuel tank of 2½ gal capacity. The engine is suitable for powering a wide range of craft, and among its many advantages is the fact that no water skin fitting connections are required, thus reducing installation costs to a minimum. The LD2 engine will also be shown as a marine auxiliary unit. In this instance it will be direct-coupled to a 3-kW, 110-V generator with a V-belt drive to a 6-cu ft, 350-psi air compressor.

A number of other examples from the established ranges of Lister and Lister-Blackstone propulsion and auxiliary engines will also be shown, including a Lister Blackstone EVMA4 auxiliary engine (180 hp at 600 rpm), direct-coupled to a 120-kW, 450-V alternator ; a Lister 616MA auxiliary engine (62 hp at 1200 rpm), driving a Hamworthy type-2TL5A air compressor for emergency duties on tankers ; a Lister FRMA2 engine coupled to a high-duty emergency fire-pump ; and two Lister propulsion engines with reverse and 2:1 reduction gear, types 3JPMGR (30 hp at 1200 rpm) and FRM6GR (60 hp at 2000 rpm).

Considerable space will be devoted by **Babcock & Wilcox Limited,** of London, N.W.1, to developments in the field of nuclear power engineering. Thus, for example, their exhibits will include a detailed sectional model of one of the thirty-two heat exchangers made by Babcock for the Calder Hall and Chapel Cross atomic power stations, and a scale model of a typical welded pressure vessel for a reactor of the pressurized-water type. Also associated with this model will be samples of a " push-out " formed in 6-in. steel plate and of a weld between very thick plates, indicative of manufacturing techniques required in the construction of reactor pressure vessels. In addition, samples of nuclear fuel cans and of the finned tubing used in a nuclear heat exchanger will be exhibited, together with a constructional model made by the Company's Research Department to assist in their building, for the Atomic Energy Authority, a piece of equipment known as the " Dido loop ", the purpose of which is to test the effect of in-pile radiation on the aqueous corrosion of water-cooled fuel elements. In the marine field, a special exhibit will be a model indicating the possible arrangement of a nuclear propulsion plant, based on a gas-cooled reactor, in the hull of a large tanker.

Conventional steam-raising plant, both land and marine, will be depicted in many aspects by a series of models and displays. An exhibit referring to oil-fired boiler plant will include a model of Europe's largest oil-fired boiler and examples of different types of Babcock

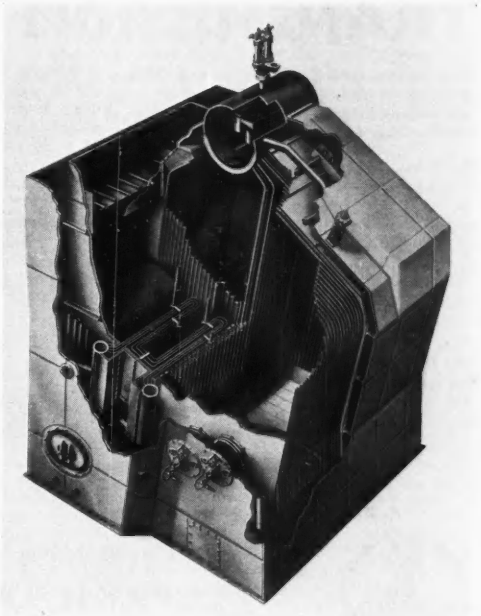

Fig. 5.

oil burners, including the new high-pressure return-flow atomizer specially developed for service on large central-station and industrial boilers. Other exhibits in this field will include Babcock patent shielded nozzles, a system of electrical sequence control which is notable for exceptional simplicity and robustness, photographs and films of cyclone-fired installations, and a sectional working model of a Babcock Type-E coal-pulverizing mill.

The main marine exhibit will give prominence to a sectional model, never previously exhibited, of the Babcock Selectable-Superheat boiler (Fig. 5), accompanied by a model of one of the many recent vessels equipped with Babcock boiler plant.

An impressive display of engineering and foundry products, covering a wide range of applications, will be exhibited by **The David Brown Companies,** of Meltham, Huddersfield, several branches of the organization being represented in a combined selection of exhibits, principal among which will be a new combined helical and worm-gear unit, a new variable-speed unit, a colliery winder-gear unit, a locomotive final-drive gearbox, a gas-turbine co-axial reduction-gear unit, and a cast-steel turbine case.

Of these, a new series of high-ratio " Radicon " helical worm-gear units is a recent development of the well-known range of " Radicon " worm reducers. Designed to accommodate the high torques experienced at low operating speeds, these combined worm and helical reduction units provide a choice of ratios from 80:1 to 250:1 in a variety of types and sizes designed to meet numerous industrial requirements. Each unit comprises a helical-gear first-reduction unit coupled to a standard single-reduction " Radicon " worm reducer, an arrangement which gives high overall efficiency. The self-contained first-reduction unit is arranged to give four alternative input-shaft positions, which, in conjunction with the two slow-speed shaft locations, provides a choice of eight different shaft-handling arrangements. The gear ratio of the helical unit is approximately 4:1, different standard ratios being fitted to the final reduction unit to obtain the overall ratio required for a specific duty.

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The colliery winder drive unit will comprise a 25-ton double-reduction co-axial gear unit with torque-balancing quill drive and final quill drive, for a tower-mounted friction winder at Killoch Colliery, Scotland. To allow for misalignment between the gear unit and the winder friction shaft and to accommodate deflection due to braking, the sleeve on which the final gear-wheel is mounted is coupled to the winder friction-wheel shaft by a torsion shaft through a gear-type flexible coupling. A pinion on the input shaft meshes with two wheels coupled to the second reduction pinions. These in turn mesh with a common wheel mounted on a sleeve connected to the output torsion shaft. To ensure equal distribution of the load among the various gears, the drive from the first reduction wheels to the second reduction pinions is through quill shafts, coupled to the first-reduction wheel sleeves by half couplings forged integrally with the quill shafts, the outer ends of which are connected to the sleeves of the second reduction pinions by gear-type flexible couplings. With the 1875-hp drive motor running at 713 rpm, the speed is reduced to about 57 rpm. Peak loads of 2750 hp (normal) and 3750 hp (maximum) are anticipated.

The locomotive final-drive gearbox is undoubtedly an interesting example of current design of rail transport drives and has been built for use with 90-mph diesel-hydraulic locomotives, nominally rated at 2000 hp. The maximum input speed to the gearbox is 2020 rpm, and the maximum input torque at starting is 110,000 lb in. A gearbox ratio of 2·84:1 and wheels of 3 ft 7 in. diameter give a tractive effort of 58,000 lb. The double reduction is by spiral bevel and single helical gears. All shafts are carried on taper roller bearings, and the case itself is of welded steel-plate construction. Self-lubrication is achieved by the provision of troughs to collect and lead to the various bearings oil splashed by the gears.

Fig. 6.

The new David Brown " Varicon " stepless speed reducer (Fig. 6), designed for drives up to 5 hp, is a hydraulically operated gear unit which provides steplessly variable output speeds ranging from the original input speed to zero and back again, whilst transmitting full rated load. Owing to the special, patented design of the gears, power is transmitted partly by hydraulic and partly by mechanical means, ensuring a higher efficiency than that normally obtainable with purely hydraulic devices of similar capacity. The unit comprises a hydraulic pump and motor (of the positive displacement type), mounted co-axially with the cylinder heads separated by a central plate, which distributes oil to the separate cylinder heads and takes the reaction of the oil pressure on the pistons. Swash-plates, mounted in substantial anti-friction bearings, operate the pistons axially. Output speed is controlled by a graduated regulator, which effects the required angular displacement of the swash-plates.

The gas-turbine reduction-gear unit is a co-axial double-reduction three-layshaft turbine gear unit, designed for use with the new Ruston and Hornsby TE gas turbine. This unit, which is designed to give a reduction from 19,250 to 1500 rpm, will transmit 550 hp. The case is of fabricated steel, with the layshafts and output shaft carried in white-metal bearings. Gear-type couplings are used on the high- and low-speed co-axial shafts, both the input pinion and output wheel being fully floating. Lubrication of the gears is by sprays and jets, and of the bearings by drilled oil-ways.

The new Ruston and Hornsby TE turbine, which will be shown in operation, is a single-shaft machine with centrifugal compressor and three-stage operation designed to drive a variety of equipment, including alternators generating up to 300 kW. The engine is built around the centre pressure casing, with the combustion chamber mounted on the rear face. The turbine and compressor are mounted at opposite ends of a common shaft, which is extended forward from the compressor to provide a drive to the gearbox.

Other David Brown exhibits will include alloy- and carbon-steel castings ; high-tensile and heat-resisting steel castings ; precision castings ; heavy-duty gears and steel castings ; floating reamers ; gear-cutting tools ; gear pumps ; Coventry geared motors ; Keighley stock spur gears ; co-axial gear units ; spur, bevel, helical, and worm gears ; and gear-type and " Cone-ring " flexible couplings.

Among the range of equipment to be exhibited by **International Combustion Limited,** of London, W.C.1, will be a section of a furnace wall, over 15 ft long and 20 ft high, which will serve to show the latest developments of cubic expansion to be used at the High Marnham power station. In addition, a new scale model of a 100-MW boiler unit for Willington power station will be shown sectioned, to demonstrate the arrangement of the combustion chamber, and will embrace the complete boiler-plant layout.

International Combustion Products Limited will feature exhibits which include grinding and pulverizing mills, filters, screens, separators, pumps, and laboratory equipment. Exhibits will comprise a " Dynocone " continuous centrifuge for continuous dewatering in collieries, and in the chemical and allied industries ; a " Vacseal " pump, which requires no sealing water and which incorporates an auto-priming device ; an " Agitair "-flotation machine for use as a cleaner, a rougher, or a scavenger in both metallic and non-metallic flotation circuits ; and a new " Rovac " filter, a new sample splitter, mills, separators, sample reducers, sieve shakers, testers, and elutriators for laboratory use.

Another member of the International Combustion Group of Companies, **Riley (IC) Products Limited,** will show a comprehensive range of Riley stokers, with machines of the underfeed type for capacities from 12 to 1200 lb of coal per hour. In addition, the Riley type-T chain-grate stoker for horizontal shell-type boilers and the Riley trickle-feed kiln stoker will be shown. Other Riley exhibits will include " Syntron " electric vibratory equipment, e.g., bowl feeders, feeders, heavy-duty feeders, trough feeders, spiral elevators, and vibrators, together with a selection of burners and an oil-fired air-heater unit incorporating a separate Riley refractory-lined combustion chamber.

Exhibits by **Carl Still Limited,** which combines the manufacturing resources of International Combustion Limited in England with those of Firma Carl Still in Germany, will show the activities of this company in the design and construction of modern coke-oven and by-product plants. A model of a coke-oven, representative of equipment supplied, will be on display, while by-product exhibits will include a model of a gas-scrubbing unit, equipment being offered for tar dehydration, benzole, ammonia, and hydrogen sulphide scrubbing ; and gas cooling and processes for the wet desulphurization of coke-oven gas and for the removal of sulphur from benzole by the Hydrofining process.

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Amongst a representative selection of exhibits of standardized control gear produced by **Brookhirst Switchgear, Ltd.**, of Chester, will be another version of the recently introduced " Chester " switchboard. This additional model, to be known as the " Chester Minor ", is designed for either industrial or marine service. It has front cabling access through a chamber at the side of each cubicle and is of smaller size, but is otherwise similar in principle to the " Chester Major " switchboard, achieving high degrees of flexibility and accessibility. The " Chester Minor " is built up from flush-fronted cubicles of heavy-gauge sheet steel. Each unit accommodates a top- or bottom-mounted busbar chamber, vertical riser bars, tiers of starters of various types and ratings, and (if required) distribution gear. The equipment is of the all isolating swing-out type (i.e., mounted on the inside of the compartment door), as shown in Fig. 7, or of the all-isolating draw-out type, according to the size of contactor or switch. Plug-in contacts for all connections dispense with trailing cables and permit instant removal of a complete starter. Interchange of similar starters or additions can be easily effected on site. The " Chester Minor " switchboard exhibited will be a marine design. It will have a drip-proof hood, packed cubicle doors, and will be painted inside and out with anti-corrosive paint, while all steel parts will be either of stainless steel or plated to prevent rusting.

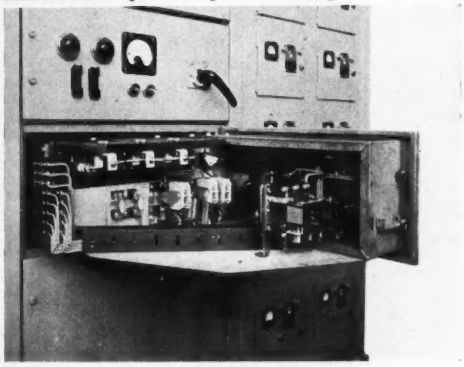

Fig. 7.

A demonstration model will show application of static switching to industrial equipment. This exhibit provides comprehensive two-speed control for a double-wound a.c. motor, with overload and earth leakage protection, embodying all the automatic features required for a large machine. A major characteristic of the control circuit is the complete absence of electrical contacts. Push-buttons and contactor auxiliary switches operate purely on electromagnetic action and, apart from these physically operated devices, there are no moving parts, all relay, time-delay, and protection features being entirely static. Short-delivery gear displayed will include individual bulkhead-mounting a.c. marine starters, a section of a d.c. open-type marine switchboard, low-horse-power a.c. industrial starters, and a full range of control accessories. In addition, photographs of gear supplied by Brookhirst to the Dounreay, Calder Hall, and Chapel Cross nuclear power stations will be displayed.

Marine exhibits by **The General Electric Co. Ltd.**, of London, W.C.2, will be representative of the company's equipment for auxiliary power services, lighting, catering, and ventilation services in ships. Among these, a section will be shown of a typical cubicle switchboard for the control and distribution of a.c. auxiliary power. This cubicle form of construction is used for main switchboards, with alternator synchronizing panels, main circuit-breakers, and feeder switchgear, and for group starter boards controlling auxiliary motors. Typical a.c. and d.c. marine motors, d.c. resistance starters, and direct-to-line starters for ships with a.c. auxiliary supply will also be featured.

A special lighting display will show colour-change and dimming effects with Osram cold-cathode tubes under the control of an electronic dimmer of the type supplied by G.E.C. This equipment, which is the latest all-electronic version, enables a range of dimming to be obtained which is virtually the same as that available with the resistance control of tungsten lamps, while taking advantage of the high efficiency of fluorescent tubes. It will operate in conjunction with four lines of cold-cathode tubing, i.e., red, blue, green, and warm white—forming an 11-ft diameter circle in a cornice arranged to illuminate a dome. Colour-changes will be made with the red, blue, and green tubes, but the warm white can be added at will to produce pastel colours. Another example of lighting practice where a.c. is available will be a new masthead fitting to take an Osram colour-corrected mercury lamp for deck illumination during cargo-working.

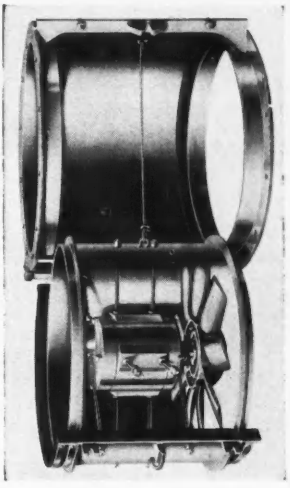

Fig. 8.

Electric catering equipment to be shown on the stand includes a two-oven range for medium-size ships and a selection of pantry appliances.

Woods of Colchester Ltd. will exhibit typical " Maxcess " fans for marine ventilation. In this design, the fan and motor are attached to a hinged panel in the ducting, as shown in Fig. 8, and are therefore fully accessible for maintenance when the panel is opened.

The Company's nuclear energy activities will be represented by a model of the G.E.C.-Simon-Carves atomic power station to be built for the South of Scotland Electricity Board ; this station will have a generating capacity of 360,000 kW and will feed an output of not less than 300,000 kW, rising to 320,000 kW, to the National Grid.

The principal exhibit by **Keelavite Rotary Pumps & Motors Ltd.**, of Coventry, will feature a one-ton hydraulic winch in operation. This winch, which is powered by a variable-speed drive giving a maximum operating speed of 80 fpm, incorporates an inching control, and the winch drum is driven by a gear-type hydraulic motor from a Keelavite packaged power unit. Speed control, including inching when hoisting or lowering, together with both dynamic and static braking, is controlled by a single lever adjacent to the winch. The high-efficiency patented hydraulically operated braking system is of special interest. This can, during hoisting, be released only when the load is already under the control of the hydraulic motor.

Also on display by Keelavite will be a selected number of units representative of the company's wide range of hydraulic power and control equipment, including hydraulic pumps and motors with displacements up to 10 cu in. per revolution and pressures up to 2000 psi, although units can be supplied with maximum displacements up to 40 cu in. per revolution at 2000 psi. In addition, a selection of hydraulic cylinders, covering bores

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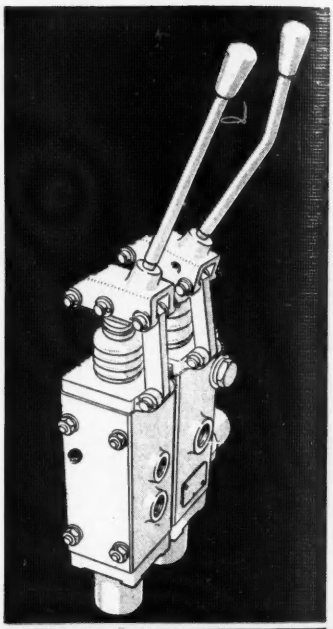
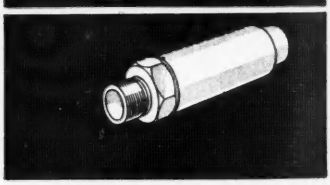
This efficient dual control valve consists of two standard Lockheed units, one controlling the tilt cylinder and one the lift cylinder on a well-known make of fork-lift truck. It can, of course, be usefully employed in many other applications. The valve for the tilt cylinder, which is double-acting, is of the 4-way type. The lift cylinder is of the single-acting type and the 3-way control valve is used. The roller on the extension is designed to operate the pump motor switch.

The unit can be supplied in a number of variations either with both 4-way valves or both 3-way valves, or with further valves to meet requirements.

Used in conjunction with this valve is a flow control valve, illustrated on the side. This is a simple but important unit which maintains, at an approximately constant rate, the lowering of the fork of the truck, regardless of the load which it may be carrying.

This is but one of many highly specialized Lockheed hydraulic units, proved in a wide range of applications.





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from 1 to 6 in. and offering a choice of foot, flange, trunnion, or clevis mountings, will be shown, together with a representative number of pressure and flow control valves and 3- and 5-port directional valves operated either mechanically, electrically, or by a servo-system. Examples of Keelavite packaged hydraulic systems, each built to suit a particular requirement, will also be exhibited.

An extremely wide range of spiral bevel, "Zerol", and hypoid gears, with diameters of from less than 1 in. up to 52 in., will be exhibited by the **E.N.V. Engineering Co. Ltd.**, of London, N.W.10, and will include what is believed to be the largest hypoid gear (Fig. 9) ever produced in the U.K. Also featured will be examples of precision spiral bevel and "Zerol" gears with profile-ground teeth, including a large spiral bevel gear for use in the main drive of a gas-turbine locomotive and a pair of narrow-angle V-drive gears with profile-ground teeth for a power-boat transmission.

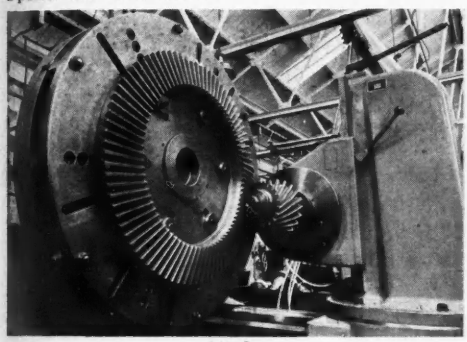


Fig. 9.

Other exhibits will deal with railway traction drives of various types, including a hypoid drive gearbox recently introduced for tramcar and railcar drives, and typical of the range of gearboxes offered by this company. In addition, the well-known E.N.V. double-reduction axle, of particular interest to builders of special-purpose low-speed industrial trucks and dumpers, will be shown.

A comprehensive range of examples of equipment made by **The English Electric Company Limited,** of London, W.C.2, will be exhibited, including items from the Diesel Division, the Gas Turbine Division, the Industrial Motor Division, the Fractional-Horsepower Division, the Control and Electronics Division, and the Welding Equipment Division.

Of these, the Diesel Division will have three main exhibits, i.e., an 8V skid-mounted drilling-rig unit, a 4S.R.K.T. traction unit, and an 8S.R.K.N. marine unit, while two main items of the Gas-Turbine Division will comprise an E.M.27 P. gas turbine with heat exchanger, and a selection of gas-turbine rotors. The E.M.27 P. compressor has six axial stages followed by one radial stage, the overall pressure ratio being 4·8:1. Air leaving the compressor is ducted either directly or via the heat recuperator to the twin, all-metal, louvred-wall, combustion chambers. The gases leave the combustion chambers at 1430°F and enter the turbine inlet casing prior to expansion through the mechanically separate compressor-driving and power turbines. These are arranged in series, each having two axial stages.

The Industrial Motor Division will include among its exhibits a range of Class "C" British Standard ventilated motors, Class "L.Y.C." British Standard totally enclosed fan-cooled motors, Class "C.K." industrial d.c. ventilated motors with Class "E" insulation, and Class "L.P." steel-barrel flameproof motors. The Fractional-Horsepower Division will feature a typical range of motors, as well as a selection of industrial hand dryers, together with a 1000-cps motor-alternator set for radar applications, and various sizes of small rotary d.c. transformers.

The Control and Electronics Division will show various items of equipment in operation, including a 35-kW R.F. induction heater, a 15-kW R.F. induction heater, a ½-hp "Magamp" magnetic-amplifier-controlled motor unit for speed and tension control, and a 2-hp magnetic-amplifier unit for motor speed control.

The Welding Equipment Division will be showing a range of portable welding equipment, including types LWC 200, 300, 450, and 600 welders, each of which is of the single-operator type and has provision for an inbuilt capacitor. Of these units, the LWC 200 equipment is used extensively by sheet-metal workers, agricultural engineers, garages, etc., while the other types are suitable for general welding applications. In addition, the Welding Equipment Division will exhibit a new welding rectifier, type LWD 350, two welding regulators, types LWR 450 and 600, and eleven types of electrodes. Of these, the welding rectifier is continuously rated for hand welding and has been designed to meet the demand for d.c. equipment. The welding regulators are employed with English Electric multi-operator equipment, as used in the shipbuilding and heavy-engineering industries, while the electrodes comprise types intended for welding various types of steel and include "Speedees" and "Hermees" fast-welding electrodes and a completely new electrode known as "Groovees". Facilities will be made available for all electrodes exhibited to be demonstrated.

A selection of Carter hydraulic infinitely variable speed gears, ranging from fractional-horsepower up to 35 hp, will be exhibited by **Carter Gears Ltd.,** of Bradford, Yorks. The display will include working and static units representative of the ten sizes at present manufactured and will be used to demonstrate handwheel, remote-electrical, lever, and hydraulic-relay speed controls. Complete variable-speed drives, including different arrangements of electric motors, Carter gears, and reduction gears, will be included in these exhibits. An illustration of a Carter "A"-type hydraulic infinitely variable speed gear, with a worm and quadrant control, is given in Fig. 10.

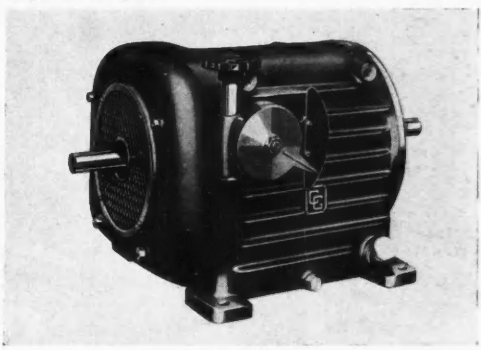
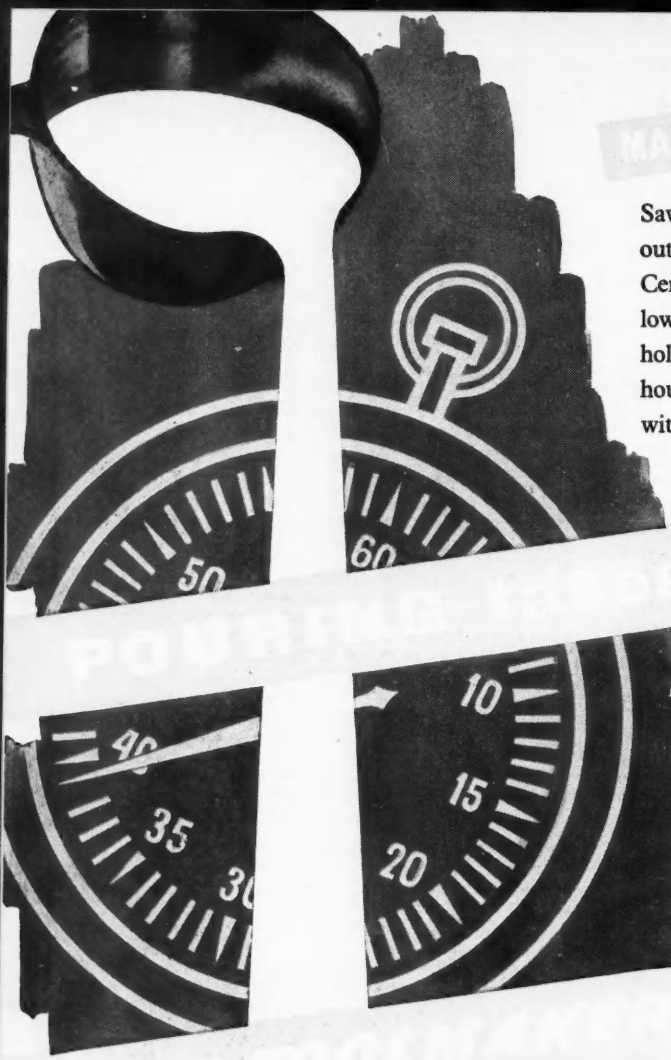


Fig. 10.

Working models, specially designed to show the principles of operation of these gears, will be shown, while a number of photographs and special displays illustrating typical applications will be used to support the actual exhibits.

Among other exhibits by **Birlec Limited,** of Erdington, Birmingham, will be a holding unit for pouring molten aluminium- and zinc-based alloys. The furnace is the recently introduced Birlec "Ajaxomatic" unit (Fig. 11), and it will be seen actually operating with a machine producing aluminium diecastings. This furnace, which features swift and automatic operation, is similar in



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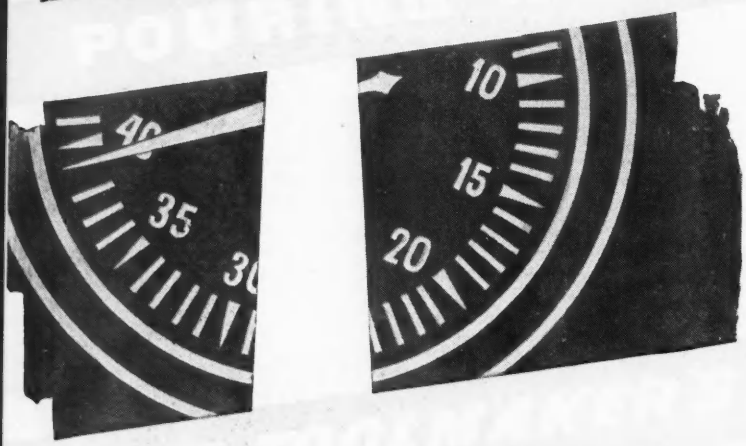

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principle to the well-known Birlec " Tama " mains-frequency channel-type induction melting furnace, and is rated at 20 kW with an average power consumption of 10 to 12 kW. Its useful molten capacity is 300 lb. The unit is remarkable chiefly for its simplicity of operation. Once the timing dials are set, the required quantity of metal is delivered directly into the chamber of the die-casting machine on pressing a button. By eliminating ladling it ensures far greater efficiency of timing and metallurgical control.

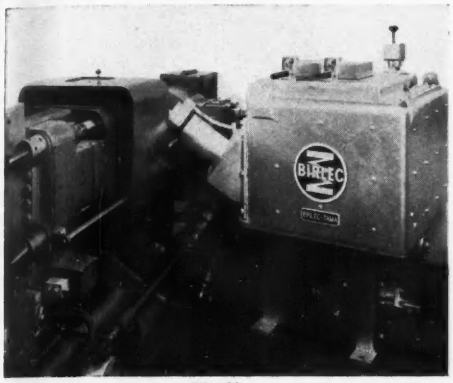

Fig. 11.

Also to be exhibited by Birlec Limited will be their recently developed sealed-quench furnace for clean heat treatment in a wide variety of applications. This furnace, which is electrically heated, ensures uniform, scale-free treatment with economy in carbo-nitriding, gas-carburizing, bright-hardening, clean-normalizing, and carbon-restoration processes. Its most unusual feature is that it makes provision for direct quenching of work without removing it from the protective atmosphere. Available in a range of standard sizes capable of handling loads averaging 200, 650, and 1400 lb, this furnace reduces labour requirements to the point where one man can easily serve three or four units.

The Engineering Components Division of the **Dunlop Rubber Co. Ltd.** will be exhibiting components made from Duthane, a synthetic rubber with exceptional abrasion resistance based on polyurethane, and a number of standard rubber products such as power-transmission couplings, anti-vibration mountings, and rubber springs.

The Belting Division will show Dunlop's new " Maxrate " V-Belt, incorporating terylene cord of exceptional strength, together with flat transmission belting for agricultural and other industries, and a range of conveyor and elevator belting of all grades and types for the cement, chemical, electrical, food, gas, iron and steel, mining, and quarrying industries, with special emphasis on heat-resisting types.

The Dunlop Hose Division will feature oil suction and discharge hoses for the loading and offloading of tankers, and expansion joints in circular water systems for use in steam, water, and oil, while the Aviation Division will display flexible pipes on high-, medium-, and low-pressure ranges for various types of fuel supply lines.

The versatility of Saunders diaphragm valves, produced by the **Saunders Valve Company Limited,** of Cwmbran, Mon., will be demonstrated by an exhibition of valves ranging from ¼-in. units for laboratory and similar duties to stainless-steel units of exactly the same type as those used for the control of heavy water in British and Commonwealth atomic reactors. In addition, both " A "-type (full-bore) and " K "-type (straight-bore) valves with pressure-closing heads will be demonstrated under power. Power demonstration by remote control will also include a diaphragm-operated pressure-opening valve in which automatic closure is provided to close the line in the event of pressure failure. Direct electric operation, typical of the system now offered with Saunders " A "-type valves from ½ to 12 in., will complete the " live " display, a 3-in. unit being featured with a " Rotork " 12B actuator.

Automatic control for fluid systems will be represented by both pressure-opening and pressure-closing valves with alternative forms of positioning apparatus. Also included in the valve display will be plastic valves for duties in acid-laden atmospheres, spherical-plug " M " valves with quick action and straight-through full-bore characteristics, and several forms of Saunders valves for wash-deck, Butterworth-system, fire-service, and other duties in ships and in shipyards.

The " Safran " pump exhibit will take the form of a working installation employing a combination of automatic float-control sump pumps and self-contained electric units. A flange-mounted pump for building-in to marine and similar engines, and a multistage pump, which can readily be converted to self-priming duties without impairing efficiency, will also be shown, together with an example of the " Safran " hot-water circulator and an engine-driven set with a self-priming pump for handling dirty water containing small solids.

The emphasis of the display of **Power Auxiliaries Limited** will be on the part being played in industry by their " Plessiflex " metallic, seamless flexible hose. Introduced as a method for overcoming problems associated with the conveyance of liquids or gases at high pressures between junctions which are initially malaligned, move angularly, vibrate, or are exposed to high and low temperatures, " Plessiflex " (Fig. 12) also provides a simple solution to problems where difficulty in using rigid piping is encountered, and is used widely for the conveyance of corrosive chemicals and gas and for vacuum installations. Apart from being extensively employed in aircraft, aero-engines, guided missiles, rocket motors, etc., this flexible hose is used in practically all other major industries.

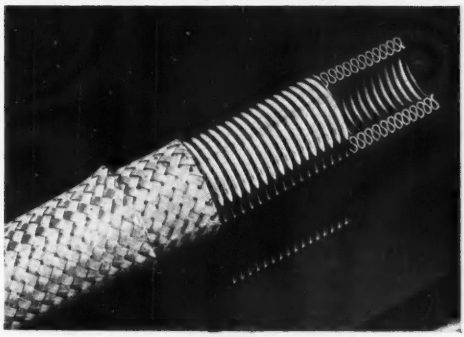

Fig. 12.

How Plessiflex is made and the various stages of manufacture will form another display. This will show a piece of stainless-steel tube followed by a length of ¾-in. diameter " open-pitch " hose and a length of ¾-in. diameter " close-pitch " hose. As shown in the illustration, the helical convolutions make the hose particularly strong yet flexible, the rib form taking strain along the entire length : moreover, it is reinforced by a single or double metallic braid, depending on working conditions.

Among a wide variety of Tufnol components made by **Tufnol Ltd.,** of Perry Barr, Birmingham, will be exhibited equipment now being used on pipelines in various parts of the world. On show, for example, will be bearing pads similar to those used for supporting the pipes in the North of Scotland hydro-electric scheme, the main reason for using Tufnol pads being to obviate corrosion within the pipes caused by electrolytic action,

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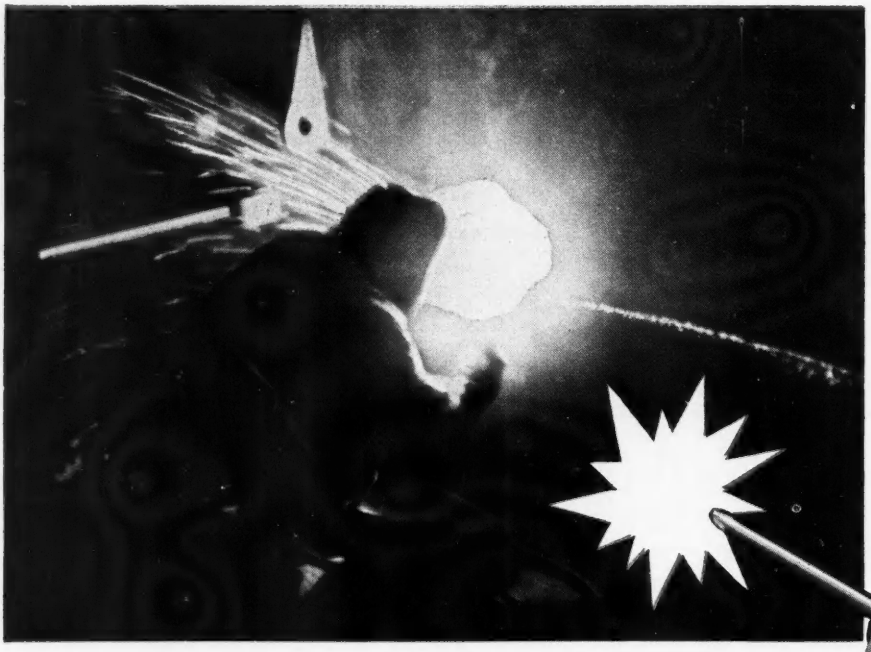

FOSTER WHEELER LTD fabricates further extensions to Esso's gigantic Oil Refinery at Fawley, Southampton

Fabrication of the REACTOR, part of the new HYDROFORMER unit being built by FOSTER WHEELER LTD. for the ESSO PETROLEUM CO., LTD. The ARCAIR Torch is being used to back-gouge the outside welds, prior to welding the inside seams. The shell plates of this vessel are 2¼" thick. Construction must meet the stringent requirements of the A.P.I.A.S.M.E. code and is subject to 100% X-ray inspection. Lincoln machines and fleetweld 5 electrodes are being used throughout.

The Arcair Torch saves on cutting and gouging up to 80%! This new patent complete unit uses only electric arc and compressed air. Air-cooled for operating-comfort, with self-aligning rotating jet for adjusting carbons to all angles. Melts *any* metal by electric arc, then dissipates the molten metal by continuous high-velocity compressed air. Special Arcair copper-coated graphite carbons, in seven sizes, are used.

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although the mechanical strength of this material, together with its hard-wearing qualities and its resistance to corrosion, also play a major part in this service. Also on show will be many items of interest to marine engineers, including Tufnol stern-tube bearings (such as that illustrated in Fig. 13), used to support the propeller shafts on ocean-going ships.

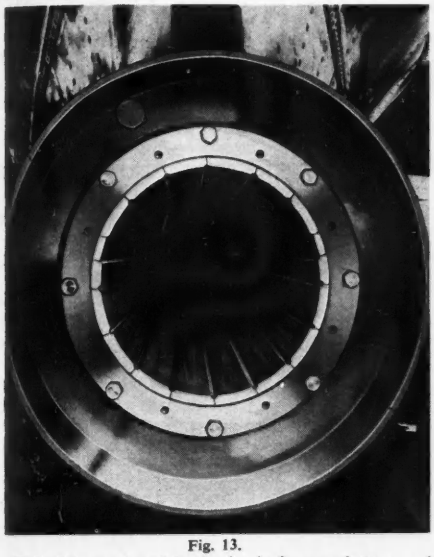

Fig. 13.

Tufnol is produced in the basic forms of sheet, tube, and rod, specimens of which will be shown, together with a variety of components illustrating its easy machinability and a number of items specially moulded to shape during manufacture.

As manufacturers of non-ferrous castings of every description, **The Sandwell Casting Co.,** one of the companies in the **Sanbra Group,** will be exhibiting a representative selection of their main specialities, including gravity and pressure diecastings, shell moulding, and sandcastings, together with a number of examples of their high-quality precision machining. Some of the bronze and aluminium sandcastings on display will have the special Sandwell " Superfyne " finish, which is an attractive matte finish, equivalent to that obtained by diecasting or shell moulding, and produced from metal pattern equipment, thus obviating the necessity for making expensive dies.

Also on show by The Sandwell Casting Co. will be the " Soundwell " factory fire-alarm bell, which is a hand-rung bell with no parts to go wrong and which saves the cost of installing an electric mains system. These bells are available in three sizes, i.e., 6, 8, and 10 in. diameter.

A typical selection of high-quality hot brass pressings, machined pressings, and assemblies will be exhibited on the same stand by **Hot Pressed Products,** another company in the Sanbra Group.

The **Owen Organisation** will be strongly represented with a selection of typical products from its member Companies. Thus, for instance, **Rubery Owen & Co. Ltd.** (the parent firm in the Owen Organisation) will be showing top-quality bolts and nuts and machined assemblies, while **Rubery, Owen Kepston Ltd.** will exhibit V-belt pulleys with a variety of applications, and **Invicta Electrodes Ltd.** will feature welding of various kinds.

Another member of the Owen Organisation, **C. & L. Hill Ltd.**, will give prominence to sandcastings in all non-ferrous metals, including aluminium, from 1 oz to 1 ton. Aluminium gravity diecastings and shell-moulded castings to all non-ferrous specifications will also be shown, together with " Hilchil " chill-cast phosphor-bronze bar, cored and solid. Finally, **Hill, Alzen (Sales) Ltd.** will demonstrate " Alzen 305 " the " white bronze " bearing alloy which, though new to Britain, has been extensively used for some years in many other countries. This alloy, which is intended to replace phosphor bronze and gunmetal as bearing materials, providing longer life with greatly reduced cost, will be shown in the form of ingots, chill-cast bars, cored and solid, sandcastings, and gravity diecastings.

The theme of the exhibits by **The Mond Nickel Company,** of London, S.W.1, will be to show how many engineering problems can be solved by the right choice of materials, and the subjects covered will include corrosion resistance, surface protection, weldability, and mechanical and physical properties. Materials will include spheroidal-graphite iron and many nickel-containing alloys and steels. In addition, a number of the exhibits will take the form of working demonstrations, while a wide range of publications will be available.

Some of the many applications of electricity to industrial heating in shipbuilding—brazing, welding, and metal melting—will be featured by the **British Electrical Development Association**. Examples will be shown of an electric induction furnace for the production of marine brass and bronze, and of machines for welding superstructures, and these will be supported by enlarged photographs of electricity in use in shipyards. In addition, examples will be shown of the latest industrial electric lighting fittings specially designed for shipyard illumination. These will be supported by enlarged photographs of modern lighting installations. Space will also be devoted to showing electrical auxiliaries to shipyards, in the form of portable electric drills, grinders, nutrunners, and riveters.

The Copper Development Association will have several interesting exhibits, showing industrial applications of copper and its alloys. One of these will be the cylindrical " basket " of a rotary laundry machine ; this unit is 7 ft long and is made of heavy-gauge brass and copper. Other items also designed to take advantage of the corrosion resistance, thermal conductivity, and strength of copper alloys will include an aluminium-bronze deep-drawing die, a gilled steam-operated copper-tube air heater, an aircraft disc brake, and a paraffin vapour lamp.

Examples of typical products will be exhibited by **The United Steel Companies Limited,** of Sheffield, of which all the steelmaking branches will be represented. Thus, exhibits will include a full range of bulb flats for shipbuilding produced by the **Appleby-Frodingham Steel Company,** who are also showing slag ballast for railway track and a model of the tanker " Haminea ", which incorporates substantial quantities of Appleby-Frodingham steel plates.

Steel, Peech and Tozer are displaying steel rings of various diameters for aircraft engines and for ball and roller bearings, pressings cold-formed from " Cor-ten " high-tensile steel strip for concrete reinforcement in buildings, and a number of forgings.

Among the exhibits of **Samuel Fox and Company Limited** will be valve and plunger springs for internal combustion engines, small stainless-steel springs for such applications as water pumps where corrosive conditions arise, and a range of stainless-steel sheets, depicting the surface finishes available.

Permanent-way materials featured by the **Workington Iron and Steel Company** will include rails, fishplates, soleplates, and steel sleepers. Workington are also showing the " Hey-back " rail-fastening system, for which they are the sole licensees for Britain and the Commonwealth.

The **Distington Engineering Company Limited** will exhibit three large ingot moulds, while models will be

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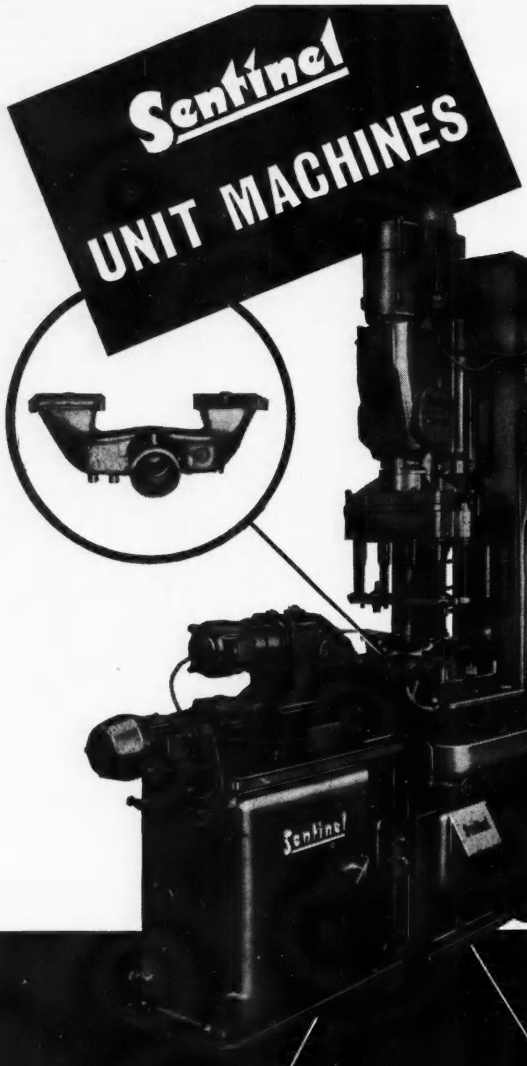
FAST VERSATILE ECONOMICAL



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3 way Centre Base.
4 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.
Bridge Column, and an EMH 20 with a 12 multi-spindle head.

Vertical Column 7,8,9 ft
3 ft. Wet Base
3 ft. Dry Base
5 ft. Dry Base
ft. Wet Base
Base for Vertical Column
4-Way Centre Base
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displayed by two other companies in the group, with the **Yorkshire Engine Company Limited** showing a model of their 400-hp " Janus " diesel-electric shunting locomotive, which is powered by two 200-hp Rolls-Royce engines, and the **United Steel Structural Company Limited** displaying an animated model of their patent " Castella " beam, which economizes in steel and reduces the dead-weight of a structure without loss of strength.

Among other items, two interesting exhibits from **Fuller Electric Limited,** of London, E.17, will be the ASEA air-operated projection welder, type SVPR 753, and the ASEA automatic flashwelder, type SVU 786-H. The projection welder (Fig. 14), which is intended for a maximum welding section of 0·38 sq in., has a capacity of 150 kVA at a 50% duty cycle and is equipped with an electronic repeat timer and an ignitron contactor with heat control and protective resistor.

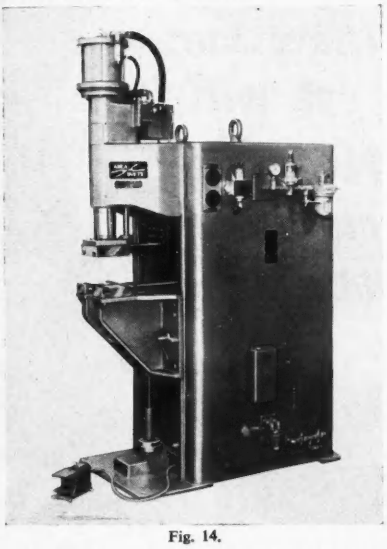

Fig. 14.

The flash welder, also 150 kVA at a 50% duty cycle, has hydraulic clamping and is designed for the welding of steel pipes with a maximum outside diameter of 5½ in. The maximum welding section is from 3·1 to 3·9 sq in., depending on tube sizes. This welder is equipped with an arrangement for reducing the inside flash caused by welding.

One of the main exhibits of the **Westinghouse Brake & Signal Co., Ltd.,** will be pneumatic remote control of marine propulsion machinery, and a working demonstration of an engine-room control layout, similar to that now being supplied for bulk sugar-carrying vessels, will be shown. This control system is suitable for a twin-engined, single-screw vessel and requires only one controlling position. When both engines are engaged, a single operating handle controls both engine throttles and also selects " Ahead " or " Astern ". Either engine may, however, be disengaged as required, and the system is arranged so that the throttle of the disengaged engine automatically comes under the operation of a separate control valve.

Another exhibit will be a display board of three sections, one illustrating the use of pneumatics for excavators, one for marine control, and one for power positioning of heavy loads.

On the electrical section of the stand the main exhibit will be a 250-kW rectifier as supplied to H.M. Navy for providing d.c. power for vessels lying alongside parent vessels. This rectifier, operating from a 440-V, 60-cps, three-phase supply, gives a 250-kW output at 225 V d.c., the output voltage being continuously and automatically controlled. Rectifiers for industrial use and battery charging will also be shown.

Among the many products which will be shown on the stand of **Murex Welding Processes Ltd.,** of Waltham Cross, Herts., are new welding electrodes, a new automatic welding machine, new welding transformers, and new welding accessories. One of the most important of the new electrodes is the " Fastex 100 ", which has been specially developed for the rapid welding of pipe joints *in situ*, and which ensures an extremely fast deposition rate and produces smooth and even welds with an absence of undercut. Another new electrode to be exhibited is the " Fortrex 35A ", which has been designed for the welding of the extra-thick plate increasingly used for nuclear-energy vessels and similar applications. The main feature of this electrode is that the weld metal provides extremely high impact properties throughout the whole section of the welded joint at sub-zero temperatures. In addition, the Murex " Suprex " range of electrodes, introduced to produce welds of high radiographic quality in creep-resisting and low-alloy steels, will be shown. It is also of interest to note that certain types in the comprehensive range of Murex stainless-steel electrodes have been modified to meet the latest requirements of nuclear fission and other high-temperature requirements.

The " Muramatic " automatic arc-welding equipment to be exhibited is suitable for use either with the open-arc process using continuous coated electrodes or with the submerged-arc process using powder flux. The welding head can be supplied either as a separate unit or mounted on a self-propelled carriage, the speed of which is infinitely variable between 8 and 80 ipm. This equipment is suitable for use with welding currents of up to 1200 A, and can be supplied with a separate power-pack consisting essentially of a Murex transformer for a.c. welding or a Murex " Dynex " generator for d.c. welding.

Also shown will be a single-operator self-contained air-cooled welding transformer, type 210, which is of an entirely new design and is an ideal welding set for small engineering shops, garages, and agricultural workshops. The current range is 20 to 210 A, and adjustments are made by means of two self-locating switches on the top of the equipment.

A new range of Murex multi-operator welding transformers to be exhibited has been introduced for 3, 6, 9, 12, and 15 operators at 250 and 350 A each ; for 3, 6, 9, and 12 operators at 450 A each ; and for 3 and 6 operators at 600 A each. The primary windings are suitable for connection to 380/440-V, 3-phase 50-cps supplies and are housed in boiler-plate tanks with elliptical tube cooling. A new type of Murex regulator has also been introduced, and the model on view, rated at 35 to 350 A for continuous hand welding, will be of the tapped type, giving 49 current adjustments. It is calibrated for use with long leads and is housed in a round tank for ease of movement. Regulators for 250, 450, and 600 A are also available.

Among the engine-driven equipment on the stand will be the latest version of the Murex " Overlander " 300/400 A mobile diesel-engine-driven equipment which has been specially designed for oilfield pipelines and similar site work. The set is powered by a Perkins P4 industrial diesel engine coupled to a Murex " Dynex " generator and is mounted on a special " Flexitor "-type undercarriage giving independent springing to each wheel.

A wide range of equipment and processes illustrating the latest developments in gas welding and cutting will be shown by **British Oxygen Gases Limited,** of London, S.W.1. Thus, exhibits will include the " Saffire " range of equipment, which can be used for gas welding, cutting, gouging, heating, flame cleaning, rivet washing, and other

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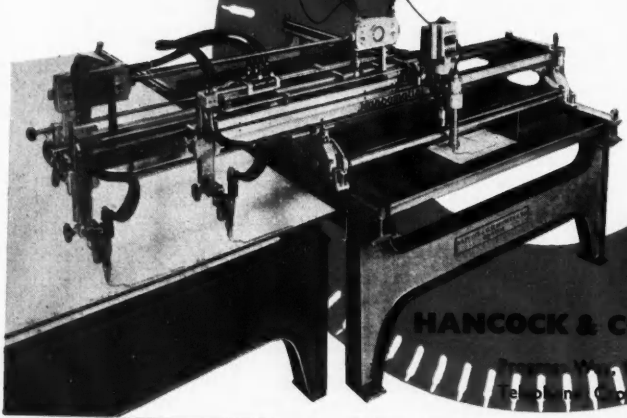

This untouched photograph is more effective than any words to illustrate the superb accuracy of Hancock machines. Made with precision and working to precision limits, Hancock oxygen cutting and profiling machines are the finest made today. No manual but a "Hancomatic" with electronic control could cut this electric motor rotor end plate. The template used is one of the rotor stampings.
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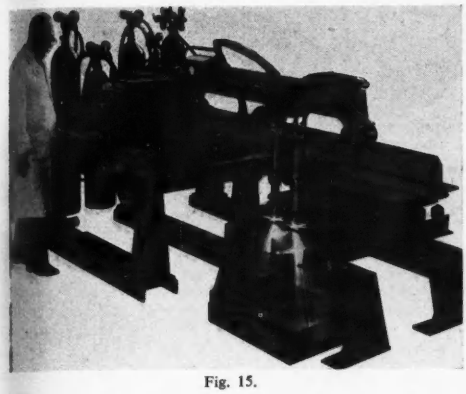

Fig. 15.

specialized tasks. Hand-cutting blowpipes from the same range, capable of cutting mild steel up to 12 in. thick, will also be shown. These blowpipes can be adapted for other cutting purposes with suitable cutting attachments.

In addition, demonstrations of machine cutting will be given, and among the machines on view will be the "Bantam 2", a portable machine weighing only 22 lb; the "Beagle" transportable profile cutting machine; and the large "Bison" oxygen profile machine (Fig. 15), capable of making profiles in steel up to 12 in. in thickness. The Company's "Argonaut" equipment will also be on view, together with the new "Argonarc" cutting process, which is being demonstrated for the first time.

The Bellows Division of **Teddington Aircraft Controls Ltd.** will be exhibiting a full range of their butt-welded stainless-steel bellows expansion joints. These bellows, which have a wide range of applications in the nuclear engineering, marine, and general engineering fields, are made from highly finished cold-rolled stainless-steel sheet of uniform thickness and are butt-welded to avoid the unequal stress characteristics inherent in bellows made from lap-welded tube. They can be used for exhaust connections, and for expansion or offset joints—in fact, wherever a corrosion- or temperature-resistant flexible connection is required. Sizes are from $\frac{3}{4}$ to 84 in. internal diameter, although bellows of larger dimensions can be made to special order. The marine applications of these bellows are particularly important both for exhaust systems and for use with turbo-compressors, where vibrations and pressures which may affect the compressor casing must be efficiently absorbed.

A range of Teddington bellows has been designed for use in the nuclear energy field, and an example with a diameter of 5 ft 6 in will be shown. One application for these atomic-energy bellows is in the main ducts which carry hot CO_2 gases from the atomic pile to the heat exchanger, requiring hinged bellows units designed for a ± 1 deg. angulation at 250-psi working pressure and 400°C and made from titanium-stabilized 18/8 stainless steel. A further application involves the use of bellows on handling machines and/or stand-pipes, where thermal expansion causes variation in the position of their end connection. Flexible bellows pieces enable any such discrepancies to be taken up. Where ducts in the body of the reactor emerge through the biological shield, a continuous seal has to be maintained, despite the expansion and contraction which takes place. Stainless-steel bellows units accommodate these movements and prevent atmospheric contamination.

Among a wide range of products, including their industrial oils and equipment, **Wakefield-Dick** will be exhibiting their type HDO mechanical lubricator, which is designed to overcome the difficulty of feeding heavy-duty marine oils through existing conventional water-filled sight-glass lubricators. The new lubricator employs valveless pump units, sight tubes through which the oil passes in the form of drops, and a separate adjustment for each pump unit. A control may also be fitted in the lubricator reservoir to facilitate the adjustment of all pump displacements simultaneously, without disturbing individual settings.

Among other items from **Crompton Parkinson Limited,** of London, W.C.2, an interesting exhibit will be their new "Cromp-Arc" J/K stud-welding equipment, which can be used for welding the popular range of studs with diameters up to $\frac{3}{8}$ in. This equipment (Fig. 16) consists of a hand-tool and its accessories, a controller, and three 15-ft lengths of flexible cable for connections. It may be fed from a "Cromp-Arc" rectifier or from any other standard source of d.c. welding current, no auxiliary supply being necessary for control purposes. The hand-tool is well-balanced and conveniently light in weight (just over $5\frac{1}{2}$ lb, with 15 ft of cable). This characteristic, together with its small size—the tool measures only $7\frac{1}{2}$ in. overall when loaded with a 1-in. stud ready for welding—and its simple trigger-button action, confer obvious advantages for operators who have to use the tool continuously. Moreover, its use on awkwardly positioned work-faces can be further facilitated by simple adjustment of the supporting foot, which can

Pressure Dependence of the Electrical Breakdown Strength of Hydrocarbons

(*Concluded from page 350*)

corresponding to the decrease in density. For nitrogen, oxygen, and carbon dioxide the decrease in breakdown strength was about 40% between 760 and 0·01 mm Hg, whereas the reduction in density was 0·15%. Therefore, in eq. (1), the coefficient K is dependent on pressure.

The tests with a propane-butane mixture showed that, even at atmospheric pressure, the breakdown strength is not exclusively determined by density. From the composition of the gas mixture and its solubility at 760 mm Hg, the calculated density of the system was 0·8346 gm/cm³, whereas the measured density was 0·8318 gm/cm³. Applying eq. (1) to paraffin oil under the test conditions mentioned gives for the constant K a value of 346 kVcm²/gm. The change in density due to dissolving the gas mixture should then have produced a reduction in breakdown strength of only about 3 kV, whereas the measured decrease was 47 kV.

Summing up, therefore, on the basis of the tests so far made, it can be said that the properties of a substance having an influence on its breakdown strength are density, as a measure of the "free volume" of the liquid; vapour pressure; and ionization energy. The assumption that a "dark" gas discharge plays a major part in the discharge in liquid dielectrics does not seem easily compatible with these results.

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Fig. 16.

be rotated around the axis of the body and clamped at the most suitable working angle. To cater for different types and sizes of studs and other attachments, a range of suitable taper-shank chucks and ferrule grips is provided (together with tools for the adjustments), and the tool itself is so designed that it automatically adjusts itself to deal with successive welding of studs varying in length by $\pm \frac{1}{4}$ in.

The controller also is of a compact design, weighing only 26 lb and measuring $7\frac{1}{2} \times 11\frac{1}{2} \times 11\frac{1}{2}$ in. high. Timing of the welding current is effected by means of a robust pneumatic device possessing a high degree of repetitive accuracy and reliability, and indication of the selected time setting is obtainable from a dial which is visible through an aperture in the front panel of the unit.

Other Crompton Parkinson exhibits will include a selection of electrical plant and equipment of particular interest to those concerned with marine and associated engineering fields. The main exhibit will be a switchboard of the type which is being supplied for the latest class of Admiralty frigates employing a.c. distribution for power and lighting. Modern in design and of noteworthy compactness, this switchboard features air-break type circuit-breakers which have passed special shock tests, as well as tests for ascertaining their fault MVA rating.

Rotating plant will include a self-regulating alternator of the Company's latest design, and a d.c. motor representing a wide range of machines suitable for shipboard, shipyard, dockside applications, etc. The alternator is of a type which has only just been put into production in the range 6 to 135 kVA, and has a " Magnicon " exciter which is flange-mounted in line with the alternator and driven direct from the alternator shaft (the armature of the exciter is quill-mounted on the extended alternator shaft). The d.c. motor is a 110-V machine with a drip-proof enclosure and will be shown complete with a marine-type terminal box, fitted with glands for v.r.i. lead-covered cable.

Also featured by Crompton Parkinson will be a representative selection of ship wiring cables, including the latest butyl rubber types, and a number of the latest types of measuring instruments. Among these are special shock-proof and hermetically sealed designs. Portable clip-on " Tong-Test " instruments will also be demonstrated.

The commercial applications to all forms of industry of their various metal-treatment processes will be shown by **The Walterisation Co. Limited,** of Croydon. Industrial products, pretreated in one or other of the comprehensive range of rust-proofing and paint-bonding treatments, will be on show or illustrated, while information regarding the latest application of new Walterisation processes for the rapidly developing industrial technique of cold-forming and extrusion will also be available.

Another new addition to the specialized treatments produced by this company will be on show. This product, called " Waltergel ", is a jelly for the removal of scale from girders, plate, and other hot-rolled steel fabrications. Other well-established metal-treatment processes which will be amply illustrated include " Foscote R.S.", " Foscote A.L.", and " Foscote G.A.", cold brush-on treatments for rusty aluminium and galvanized surfaces ; " Deran ", comprising solutions for derusting and passivating ; " Walterisation L.", a chemical oxidation process for aluminium ; and " Walterblak ", a black decorative finish for steel.

Carbon-Brush Friction and Chatter

(*Concluded from page 354*)

A means of varying the point of application of the friction force appeared to be feasible when the effect of varying the interpole strength of a machine was considered. If the interpole current is increased, the load current tends to concentrate in the leading edge of the brush. Since the wear rate of brushes is higher with current than without, the leading edge would tend to operate at less pressure than the trailing edge. This would put line *OA* in Figs. 1 and 2 in the position shown in Fig. 4b, and the brushes would not chatter. On the contrary, if the interpole current is decreased, the load current concentrates at the trailing edge of the brush, and the pressure under the leading edge is increased. Line *OA* in Fig. 4a is in the chatter range. To prove this, a 25-kW, 120-V d.c. generator with radial brushes, as shown in Fig. 4, was operated under these conditions. As predicted, the brushes chattered when the interpole strength was decreased, but did not chatter when the interpole current was normal or increased.

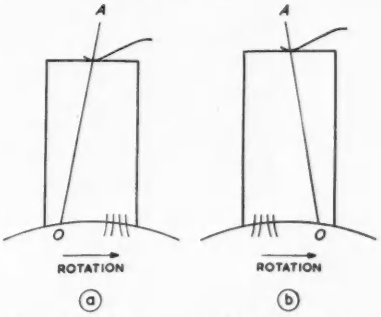

Fig. 4. Effect of increasing or decreasing interpole strength on the brush current and stability of a generator.
(a) Interpole current decreased (buck).
(b) Interpole current increased (boost).

This effect has been demonstrated in the sound film, in which a meter represents the variation from normal interpole current. A full-scale deflection to the right represents a 30% decrease in interpole current, and a full-scale deflection to the left a 30% increase in interpole current. The difference can be detected by ear when the machine is running, but this difference could not be picked up on the sound film because of the background noise. However, by permitting the machine to coast to a stop after about 15 min running under the three conditions (1), (2), and (3) mentioned above, the squeal can be heard just before the machine comes to a stop after running with decreased interpole strength. This experiment indicates the relationship between the electrical and mechanical characteristics of rotating machines.

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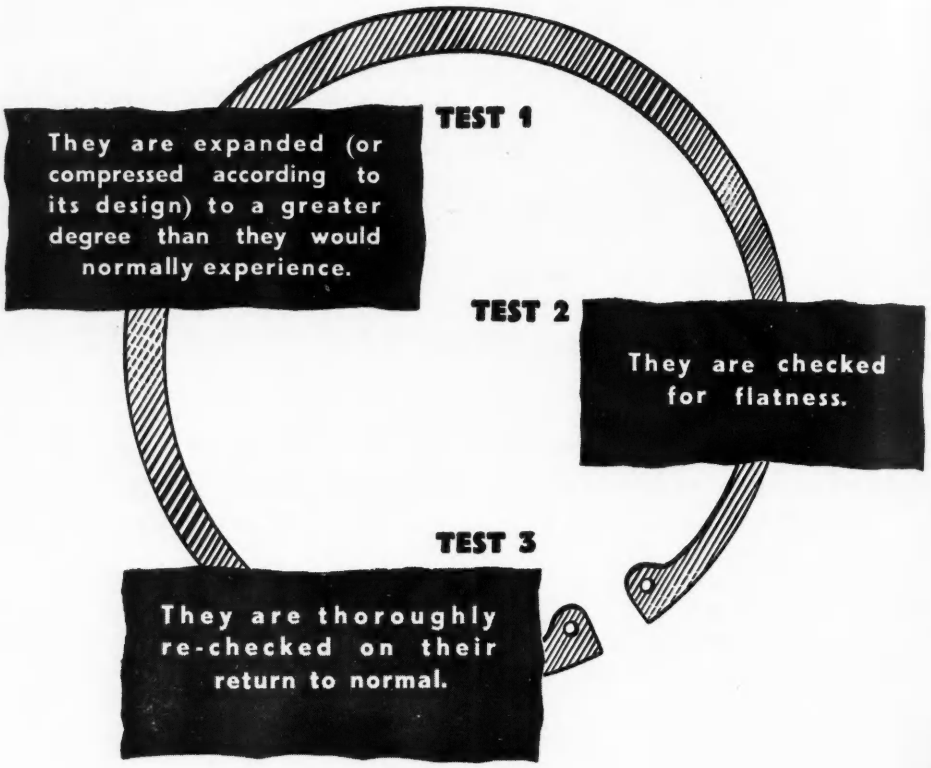
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British Industrial Developments

Mechanized Handling Plant for the Fabrication of Steel Sections

Details of the mechanized handling plant for the fabrication of steel sections marketed by their organization have been announced by Boulton & Paul Limited, of Norwich. The basic object of the system they have adopted is the elimination of template making and marking off, as well as a reduction in the actual handling of steel bars. As a result, the amount of labour required for the preparation of sections has been considerably reduced, output has increased, and considerable floor space has been saved for other work. Contrary to accepted practice, bars now travel from the stockyard through the cutting and machining processes without the use of a crane, except at the start and finish. It should also be noted that, although Boulton & Paul developed this plant primarily for their own use, it has now been decided to manufacture it for general sale.

The restyled plants now in production consist essentially of a continuous conveyor, approximately 250 ft long, with storage benches. Sawing and drilling machines are positioned along the length of the conveyor, in order to deal with work in the correct order, the storage benches being necessary to act as a " buffer ", on account of the different speeds of operation of the machines working on different jobs. The equipment is designed to handle all structural steel specimens, including broad flange beams up to 33 × 15 in. and stanchion sections up to 18¾ × 16¾ in. in lengths up to 60 ft and weighing 426 lb per foot.

In the background of Fig. 1, which shows the general layout, can be seen the feed bench to the cold saw (not shown in the photograph), on which bars are placed by an overhead crane in the stockyard. The bars are then fed through the saw and, after cutting to length, move to the conveyors leading to the horizontal drill unit (right centre). The bars are then processed through this machine and automatically conveyed to the vertical drill in the foreground.

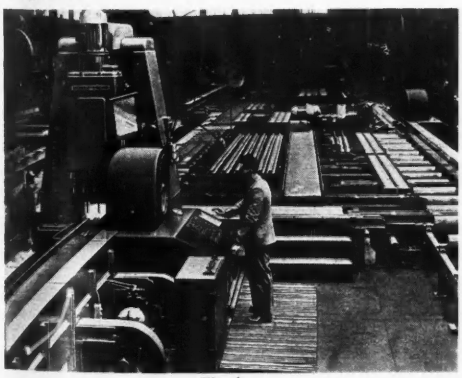


Fig. 1.

When the appropriate button on the control bench is pressed, the bar is drawn across the feed bench by dogs fixed to an endless chain and onto the roller conveyor which leads into the saw, and which travels at 10 or 60 fpm, as desired. A mechanical device centres the bar on this conveyor, which, with the self-centering vices of the saw, ensures that all sections are cut exactly square.

The vertical sawing machine (Fig. 2), manufactured by Clifton and Baird Ltd., of Johnstone, has a 44-in. diameter saw blade and is equipped with self-centering, mechanically operated vices on either side of the saw blade, thus enabling a section to be trimmed at both ends, while still providing the rigid clamping necessary for the sawing of either single or batches of bars. These vices are driven by a reversing motor through gearing and are controlled by push-buttons from the operator's desk. A hydraulic feed to the saw is incorporated, giving infinite variation in saw traverse up to 25 ipm, together with automatic quick return at the end of the cutting stroke. Suitable saw speeds are also provided for the various classes of materials now in common use.

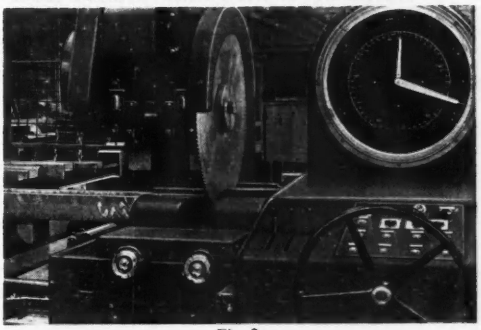
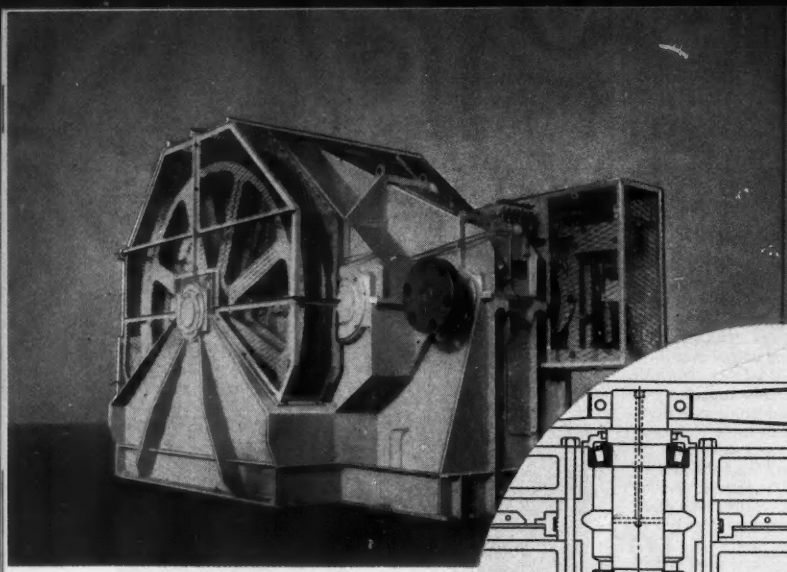


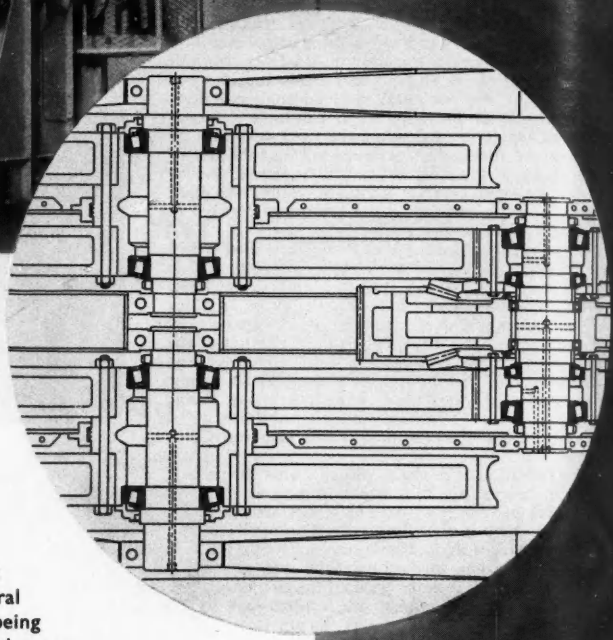
Fig. 2.

In operation, the stock bar is first fed into the saw vices. A trimming cut is then taken off the leading end of the bar, in order to provide a surface from which accurate lengths can be taken. The bar is then traversed through the machine at the rate of 60 fpm. When the clock-type dial indicates that the required measurement is being approached, the operator pushes a slow-speed button and brings the bar to within an inch of the exact measurement required. Then, by a simple movement, he engages a handwheel control and inches the bar to the exact dimension. When the bar has been carried through the vices, it passes to a second roller conveyor on the other side of the machine and thence to the drilling operators. Movement of the bars between the machines is made automatic as far as can be effected with safety. The disposal of bars from the machines is entirely automatic, and no attention is required from operators.

The measuring equipment consists of an endless chain supported on its rollers throughout the length. As it is maintained at a constant tension, its movement drives the measuring-dial spindles through suitable sprockets as the feeler arm travels along with the bar. This feeler arm is kept in close contact with the end of the bar by a drive mechanism which ensures that a constant pressure is exerted by the bar against this feeler; the distance travelled by the feeler is therefore measured by chain pitches rather than absolute distance. To ensure that accurate lengths are obtained, means are provided to compensate for chain wear and stretch throughout the length of the chain and, by this means, lengths of up to 60 ft can be measured with great accuracy. A similar measuring equipment is fitted to the two drilling machines of the plant and is used to determine the position of the various holes required along the length of the bar.

The next unit in the line is a duplex multi-spindle horizontal drilling machine (Fig.3), manufactured by James Archdale and Co. Ltd., of Worcester. The two heads are each fitted with two banks of three drill spindles, each bank being adjustable vertically on the





On a cable belt conveyor

A new type of belt conveyor designed and built by Cable Belt Limited is installed in a number of mines and collieries in Great Britain and overseas. The conveyor has several novel features, the most important of these being a pair of steel wire ropes, one on each side of the conveyor, and these, instead of the belt, take the driving pull.

Moulded within the belt transversely at suitable pitch are spring-steel cross straps which enable the belt to trough under load, and a shoe form is moulded on to each edge of the belt, which allows the belt to sit on top of the driving ropes.

The photograph shows a typical driving unit and the line drawing a part section of it, with its numerous Timken tapered-roller bearings.

Characteristics of a typical conveyor installed are length 8,130 feet, with a lift of 213 feet: belt width is 42 inches, speed 325 feet/minute, the driving ropes are 1¼ inches in diameter.

The conveyor handles 600 tons/hour R.O.M. Coal, and requires 330 H.P. to drive.

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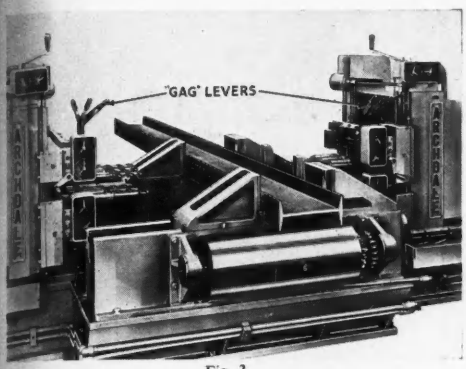

Fig. 3.

head slides. The centre spindle of each bank is fixed laterally, while the two outer spindles can be moved in this direction from a minimum distance of 2½ in. from the centre spindle to a maximum of 6 in. The vertical movement is sufficient to drill at the normal cross-centres on flanges ranging from 16¾ to 3 in. in width. Using the lower bank of drills at its lowest position of ¾ in. above the feed roller and again at 2½ in. above the feed roller, it is possible to drill holes at 1½ in. centres on a 3 in. flange. This double operation is necessary, because the minimum centres of drill banks are 2½ in.; however, with all other flange widths up to 16¾ in., the holes can be drilled simultaneously at the normal cross-centres. By the use of this layout, any holing pattern commonly used in structural steelwork can be drilled without difficulty. As it is not always necessary to drill six holes at a stroke, the drills are arranged so that any spindle can be made inoperative. To ensure that the position of each spindle is visible to the operator, dials are provided, giving the lateral position of the outer spindles and the vertical position above the top of the rollers of the two banks of three in each case. Adjustments can rapidly be made in drill centres to an accuracy of 0·015 in., and, as a result of the rigid housings for the drill spindles and the fact that the bars are firmly clamped in the vices of the machines, very great economy is made in the life of the drills.

All movements of the machine are controlled by push-buttons on the control desk. When the "start" button is depressed, the heads move forward at the fast traverse rate of 16 fpm, until the drills are almost in contact with the face of the work. The speed is then automatically changed to the correct drilling feed and, when the drills have broken through, the head returns at the fast speed. Hydraulic drill feed gives an infinitely variable range of speeds up to 6 ipm; four spindle speeds, ranging from 120 to 465 rpm, are available. Measurement starts as the end of the bar reaches the centre-line of the centrally fixed spindles, and continuity of drive for the bars through the machine is attained by four built-in rollers which are mechanically driven from the main conveyor system. When the work is in the required position in the machine, it is gripped by two hydraulically operated vices, while a third vice grips the end of a bar when it is clear of one of the vices. To deal with the large quantities of swarf made by these twelve spindles, a shaker conveyor is installed under the drills, carrying the swarf into a container situated in a pit at one end of the machine. The bars are automatically removed in the same way as from the saw and then proceed to a vertical machine for drilling the webs.

This next unit is a multi-spindle drill, also manufactured by James Archdale and Co. Ltd., of Worcester, and has either four or six spindles arranged in line. The machine is designed to drill holes across the web of all sections up to 33 in. wide with six spindle heads, or 19½ in. with four spindle heads, and can also be used for drilling batches of small angles or channels. Fig. 4 gives an indication of the layout of the four-spindle machine installed in Norwich. The spindles are adjustable to any position across the width of the web, the only provision being that the minimum centres which can be drilled are 2½ in., unless the holes are drilled singly. Each spindle is gagged, as in the horizontal machine, so that, again, any number of holes from one to six can be drilled at a stroke. Hydraulic feed for the drills is provided, with automatic changes in feed from fast advance to drilling feed and then to fast return. The same range of feed and spindle speeds as on the horizontal machine is available. From this machine the bars are automatically conveyed to the assembly benches where the necessary fittings, prepared by similar methods, are attached.

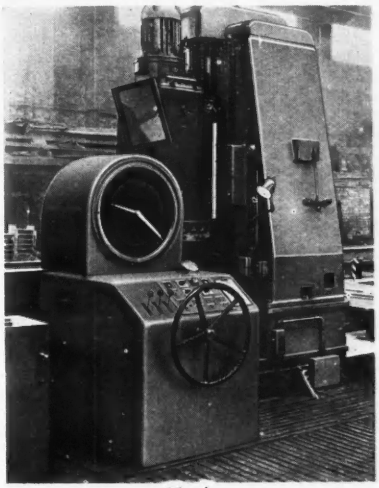

Fig. 4.

Throughout the plant great attention has been paid to the safety of personnel and machines. Stop-switches are provided in all the positions where danger might arise, and the various electrical controls are interlocked as far as possible, to ensure safe operation. A further precaution has been taken where the travel of bars might cause damage, should a limit-switch fail. In these cases the appropriate switches have been duplicated throughout, so that, should the operating switch not function, the safety switch will come into use at once; a warning light immediately appears on the desk of the operator controlling this part of the system, so that he is made aware that one of the switches is out of order. Finally, all the circuits have been arranged so that any failure will be to safety.

Heavy-Duty Wood-Turning Lathes

As a result of the recent redesign of their range of heavy-duty wood-turning lathes, the latest type R.U.H. lathe manufactured by Wadkin Ltd., of Leicester, is built on more substantial lines. Thus, the headstock now incorporates a heavy spindle, which is mounted on taper-roller bearings. Each end of the spindle is prepared to receive a flange-mounted faceplate, and the front end is bored to receive centres. The drive is from a motor mounted inside the large headstock, driving a nine-speed gearbox giving speeds ranging between 100 and 1900 rpm. Power is transmitted from the gearbox to the main spindle by multiple Vee-belts. Speeds are quickly selected by a simple lever movement on the front of the headstock. A lock is provided to the spindle, to facilitate setting, and is interlocked electrically with the driving motor to prevent the machine being started whilst the

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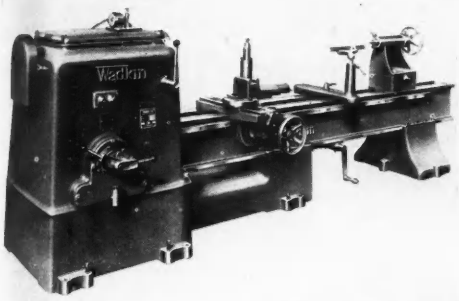


spindle is locked. A powerful brake is also provided, the operation of which automatically switches off the motor.

The bed is arranged with a sliding motion by rack and pinion away from the headstock, to give any required width of gap. The largest diameter that can be turned within the gap is 5 ft. Up to 7 ft diameter can be turned on the outside faceplate. Three sizes are being built, with 12, 15, and 18 in. centres respectively, and all machines have a bed length to take up to 8 ft. 3 in. between centres with the gap bed closed. The tailstock is bored out and fitted with a long steel sliding poppet, controlled by a large handwheel and square-thread screw. It is arranged with set-over motion by screw for taper turning. The front end is bored out the same size as the headstock spindle. The centres are self-discharging.

A travelling-slide tool-rest can be supplied, having a lateral movement along the bed controlled by rack and pinion and a cross motion controlled by a square-thread screw. The tool post is slotted to receive the tools, which can be swivelled in any direction. A spacing collar with ball seating enables tools to be canted in the tool post at any required angle in relation to the job.

Pilot Plant for Refining Hydrocarbon Oils

The erection of a pilot plant for refining crude benzole, naphthas, and other hydrocarbon oils, which has been built at the works of Newton, Chambers and Company Ltd., of Thorncliffe, Sheffield, is the first result of an agreement made between this Company and the Coal-Tar Research Association. A hydro-refining process of improved efficiency has been developed for continuous operation, as a result of research carried out by the Association since 1952, and the Company has now acquired world rights for manufacturing the plant to operate the process. It is expected that, through the use of this new type of plant, a considerably increased yield of motor-spirit of greater purity can be expected.

The new hydrogenation process employs pure hydrogen, or hydrogen containing gases such as coal gas or coke-oven gas in combination with a particular catalyst for the preferential hydrogenolysis of sulphur compounds, gum-forming olefines, and colour-forming bodies. It has been developed for continuous operation, which can be completely automatic, ensuring that the refined products are consistently in accordance with the designed specifications. In contrast, somewhat uncertain results are achieved by present methods of refining benzoles and naphthas by batch or intermittent processes of agitation with concentrated sulphuric acid. Furthermore, the commonly used acid-washing process results in considerable losses of spirit and the production of "acid tar", disposal of which is extremely difficult, while naphthas cannot always be satisfactorily refined by washing with concentrated sulphuric acid.

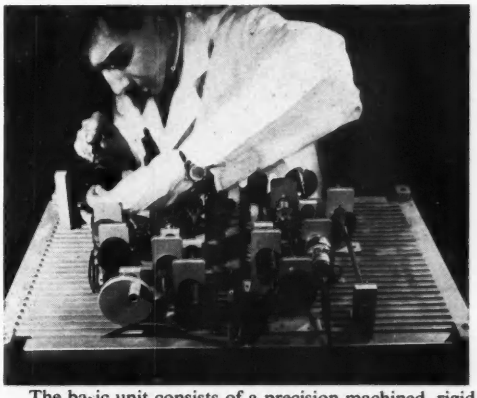
The new process differs from other refining processes for crude benzole by employing a considerably shorter contact time. In this way there is a higher output obtained for a given size of converter, and the operation for naphtha refining is at a considerably lower pressure. This is of special importance, because the consumption of hydrogen in naphtha refining is greatly reduced—with consequent economy—and the undesirable conversion of aromatics to naphthenic hydrocarbons is minimized.

The choice of hydrogenating gas and the general operating conditions best suited for the desulphurization of a particular feed stock or range of feed stocks can at present be quickly ascertained in a small laboratory-scale unit; the pilot plant, however, will be capable of dealing with 500 gallons of feed stock daily, and will be used to determine optimum operating conditions, together with all chemical engineering data for any crude benzoles and naphthas. Its capacity will be such that the products will be in sufficient quantity for market research or further investigation.

It is considered that hydrogenation is of very great potential as a chemical engineering tool generally, and in the coal-tar industry in particular. In this respect, it is worthy of note that this pilot plant has been designed for wider operating conditions than those required for the hydro-desulphurization of benzoles and naphthas, so that it can be readily adapted for further investigations and development work in this field.

Breadboard Components for Servo-Laboratories

Designed to break the bottleneck in servo-laboratories occasioned by the translation of schematic servo-designs into a working model, a carefully considered scheme of breadboard components is now being manufactured by Vactric (Control Equipment) Limited, of London, S.W.1. With these components, servo-laboratories can proceed directly from the schematic to the breadboard stage in a matter of hours, instead of, as used to be the case, a matter of weeks. Thus, for example, the servo-equipment shown breadboarded in the illustration was assembled, wired, and ready for evaluation in a few hours, whereas, had it been made by the customary procedures, it would have taken at least eight weeks.



The basic unit consists of a precision-machined, rigid duralumin baseplate supported on four legs, which can be placed in any convenient position during assembly. This baseplate incorporates a large number of slots, making for easy positioning. The component supports, made from high-grade duralumin extrusion, precision jig-bored and machined to close tolerances, have been designed to accommodate many of the standard international frame-size servo-components, although, where non-standard units are used, the system lends itself to easy adaptation. These components are secured to the baseplate by means of locating blocks.

The shaft supports are jig-bored and fitted with pre-

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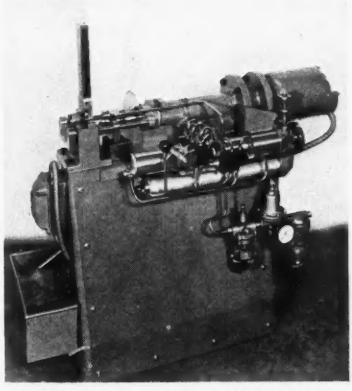
cision ball bearings which carry the basic ¼-in. diameter shaft system. Also supplied are terminal block supports ; locating blocks ; shaft-angle indicators marked in degrees ; shaft couplings, which have no backlash, allow considerable misalignment, and can transmit up to 20 lb-in. torque ; shaft adaptors, which are used to increase artificially the diameter of component output shafts, so that they may be conveniently coupled to other components ; crank handles for manually operating input shafts and pulleys for applying load torques to output shafts. A range of gears of 80 D.P., 20-deg. pressure angle is also available to suit the ¼-in. diameter shafting, and these provide for between 45 and 350 teeth with a face width of ⅛ in. All breadboard components can be supplied individually, and special designs can be manufactured to meet specific requirements.

Machine for Back-Chamfering Hexagon Nuts

A machine for back-chamfering hexagon nuts, recently constructed by W. J. Meddings Limited, of London, W.1., demonstrates how their " Pacera " horizontal drill head can be used in the construction of simple single-purpose machines. This particular machine is capable of back-chamfering thirty ¼-in. steel nuts per minute, and one operator can easily feed three such units.

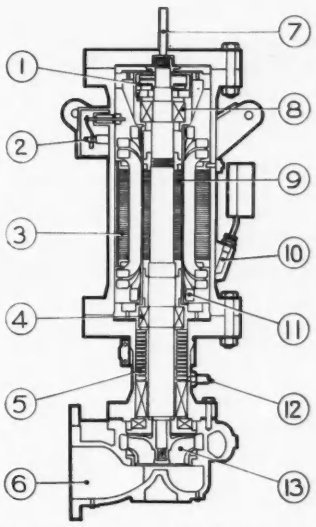


The machine works automatically and has a magazine-fed jig of simple construction. In the model illustrated, the magazine is fed by hand, but a vibratory hopper or automatic feed could be added. Furthermore, direct feed from the automatic lathe could be arranged. Nuts are released one by one to the jig, where they are clamped and chamfered. Ejection is automatic and the finished parts are collected in the receptacle shown.

Glandless Circulating Pumps

Designed primarily for circulating hot water in the heat-exchange systems of steam generators, the glandless circulating pumps manufactured by Hayward Tyler & Co. Ltd., of Luton, are leak-proof and intended to run for long periods without maintenance. As such, they have been installed in the Calder Hall nuclear power station, and are on order for the new stations at Chapelcross, Dounreay, Hunterston, Bradwell, and Berkeley.

As distinct from the canned type of glandless circulating-pump motor, the motor used in the Hayward Tyler pumps uses plastic-insulated wire and relies on water for cooling. The cables are brought out through the motor through self-sealing stationary cables. As the water to be pumped is generally at a very high temperature, a certain amount of heat flows from the pump to the motor. In this design, heat flow is greatly diminished by the provision of a separating neck of reduced diameter,



(1) Thrust bearing.
(2) Cable entry.
(3) Stator.
(4) Journal bearing.
(5) Thermal baffle.
(6) Pump suction.
(7) Cooling-water inlet.
(8) Journal bearing.
(9) Rotor.
(10) Thermometer.
(11) Motor windings.
(12) Cooling-water outlet.
(13) Pump impeller.

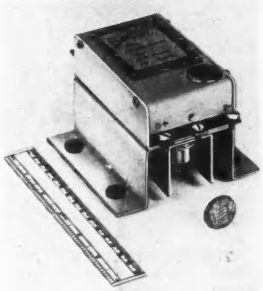
fitted with a series of stationary baffles, as shown in the illustration, designed to minimize thermal convection.

In order to keep the bearings in cool liquid, they are housed in the motor enclosure, and the pump impeller is mounted on an extension of the motor shaft. It is usual for such pumps to work at suction pressures not much above the vapour pressure of the liquid, so that special impeller designs are needed. The impeller generally provides a measure of axial balance, the remainder of the axial thrust being carried by the thrust bearing.

Electronic Transistor Regulator for Low-Voltage Generators

A new transistor regulator for providing electronic regulation of low-voltage generators for automobiles and commercial vehicles is announced by Simms Motor Units Ltd., of E. Finchley, London, N.2. The unit, which is small and compact, has no vibrating contacts, is reliable and easy to adjust, and is capable of very close control under all conditions. Furthermore, it cannot cause radio or television interference.

These units are not as yet available commercially, though it is hoped that models suitable for all automobile, commercial, and passenger vehicle applications will be produced in the near future, as the outcome of particularly encouraging results with experimental units. In the circuit undergoing tests, control is maintained over voltage and current. A grounded emitter circuit is used with silicon voltage and germanium current reference diodes. Blocking is effected by means of a germanium diode, while an " assurance " light connected in the circuit provides a non-linear resistance in operation.



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New Materials, Processes, and Equipment

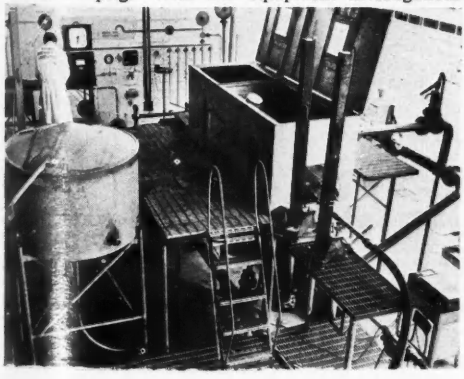
SHELL-CORE BLOWING MACHINE

Stated to be the largest of its type in the world, a new shell-core blowing machine developed by the Shallway Corporation, of Connellsville, Pa., stands 7 ft in height and occupies a floor space of 3 × 8½ ft. It is fully mechanized for push-button control, eliminates the need for dryer plates and core ovens, even for the largest cores, and is designed for core-boxes up to 18 × 30 × 12 in. across the parting line. It can, if desired, be altered to accommodate core-boxes up to 36 in. in length.

The core-box halves are mounted on electrically heated cast-iron plates, which are opened and closed by means of electric motors. The sand is blown into the box under pressure from an accumulator tank, and the unit is then inverted to return the excess sand to the blow-head. After a short period, the core-box opens and the finished core is removed. Completed shell cores are produced at a rate of about one core-box per minute. Since the core is cured in the heated core-box, there are no subsequent handling operations.

TEST FACILITY FOR HIGH-SPEED AIRCRAFT FUELLING OPERATIONS

Designed to meet the rapidly growing requirements of high-speed aircraft fuelling systems, a new test facility developed by the Parker Aircraft Co., of Los Angeles, Cal., is intended to simulate complete in-flight and ground high-speed fuelling operations in modern aircraft and is capable of pumping up to 1800 US gal per min at 75 psig. With this equipment investigations can conveniently be made of a number of conditions, including pressure drop, overshoot, surge control, opening and closing level, and leakage.

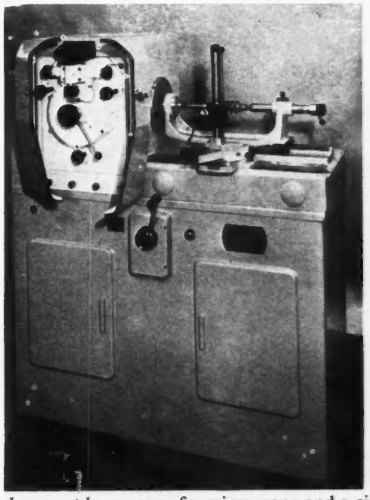


Covering 5000 sq ft, the new test area has an underground storage capacity of 10,000 US gal, 6000 gal of which can be recirculated during tests. Special valve systems permit external fluid supplies to be fed into the system. In addition to the 1800-gpm general-purpose test equipment and instrumentation, the facility includes a 400-gpm environmental test section for tests between −65 and +250°F.

One area of the test facility is shown in the illustration. The cylindrical tank at the left and the two on the right can be switched into the high-flow circuit of 1800 gpm automatically. Lights indicate which valves are opened and closed and which portions of the circuits (shown schematically on the panel in the background) are activated. Lines can be remotely opened and closed automatically, to provide the proper amount of flow in the required direction.

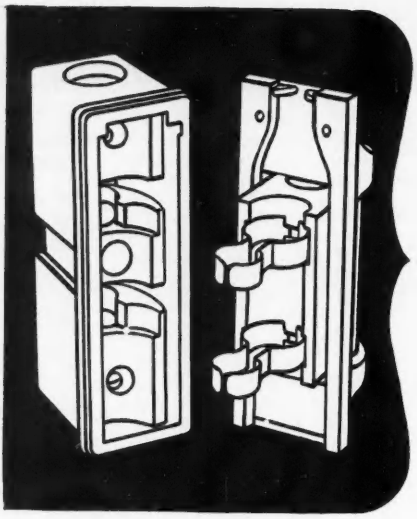
LEAD-MEASURING MACHINE

The unique design of the helix-generating system in the lead-measuring machine announced by J. Goulder & Sons Limited, of Kirkheaton, Huddersfield, enables leads from zero to infinity to be measured. As a result, any gear from a straight spur type to a worm can be quickly and accurately measured. In addition, hobs can be checked, thus providing a valuable control of product accuracy.



Leads are set by means of a microscope and a circular glass scale. Short leads with a number of turns presenting a long developed measured path may be set by the microscope and checked precisely by means of a slip-gauge holder attached to the spindle. Movement of the quill is controlled entirely by an electric motor and is therefore free from variations occasioned by the techniques of different operators. Errors of lead can be read from a high-magnification micro-indicator or can be recorded on a special recorder which provides a variable magnification between ×100 and ×5000.

The machine is started by operating a control lever, causing the quill to unlock and the gear under test to move through the lead set on the scale. When the control



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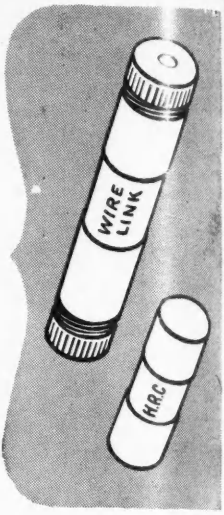

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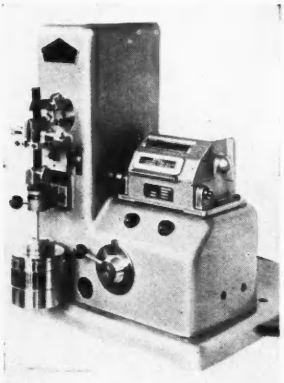
lever is released, the quill reverses and the gear returns to the initial position, when the quill locks again. Safety of operation is ensured by limit-switches. When the quill reaches the outer limit of its travel, it stops and can only be started in reverse.

BENDING-FATIGUE TESTER FOR SHEET MATERIALS

Specifically designed for determining the durability of materials such as thin sheet metal, metal foils, etc., the new model No. 954 bending-fatigue tester announced by Karl Frank, G.m.b.H., of Weinheim-Birkenau, Germany, is provided with an infinitely variable motor, permitting any number of load cycles to be applied between 110 and 1000 per minute, adjustment being made on a scale conveniently located on the front of the housing.

The specimen is bent through an angle which is adjustable between 0 and 90 deg., and test loads from 100 to 5000 grams may be selected. For accurate adjustment of the bending edges two micrometers are provided; these micrometers also serve for fixing the bending point. Vertical displacement of the part carrying the bending edges is controlled by a vernier with an accuracy of 0·1 mm.

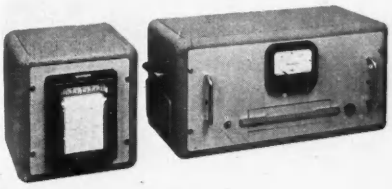


After breakage of the test specimen, the machine switches itself off automatically, and the number of load cycles is registered on a built-in counter. Alternatively, if desired, it is possible to preselect any given number of load cycles and, when this number is reached, the machine also stops automatically.

METER FOR MEASURING THE BENZOLE CONTENT OF COAL GAS

A new benzole meter which will give a rapid and accurate measurement of the amount of benzole present in rich coal gas, or left in the gas after the extraction process, has been developed by Hanovia (Lamps Division of Engelhard Industries Ltd.), of Slough, Bucks., in conjunction with the research department of National Benzole Ltd. This meter, which is compact and portable, will measure 0·1 to 6·0 grams of benzole per 100 litres of coal gas. However, it can be adjusted, when required, to show a full-scale reading for 4·0 grams per litre of gas. It will respond almost identically to benzene, toluene, or xylene, and will also respond in varying degrees to other important vapours with high absorption in the ultra-violet region around 2·537 A.U. The vapours of such compounds as trichloroethylene, methyl ethyl ketone, and styrene will show varying degrees of absorption in this short ultra-violet region, and the meter will also prove useful for estimating a number of other organic compounds in the vapour state.

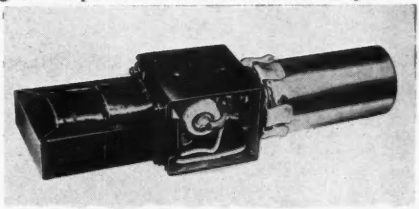
The operation of the unit depends on the characteristic absorption values of certain organic and inorganic compounds in vapour form to selected ultra-violet wavelengths. It comprises a sensitive photo-electric photometer, in which a fixed-length gas cell is interposed between a low-pressure mercury-vapour tube —substantially monochromatic—and a photo-electric detector with a quartz envelope. The photo-electric cell is arranged to unbalance a dual-pentode bridge circuit



when the transmission path is influenced by the presence of benzole. The meter mounted on the front panel indicates the state of unbalance in the bridge circuit and thus the amount of benzole in the chamber. The drive supply to the ultra-violet source and to the bridge circuit is stabilized against changes of voltage and frequency of the supply line. Once set up, the equipment may therefore be considered as stable over considerable periods of time. All circuit adjustments are preset, except for the nominal supply voltage selector and the remote/internal indicator selecting switch, and require checking only at about four-monthly intervals, depending on the amount of use the instrument receives. The inside of the absorption cell is nickel-plated to withstand any corrosive effects from the coal gas passing through the cell, and the presence of other constituents in coal gas does not interfere with the normal operation of the meter. If the H_2S content of the gas is high, it may be necessary to interpose a small absorption tower between the gas supply point and the meter.

SELF-CONTAINED LOW-VOLTAGE FLUORESCENT LIGHT UNITS

Facilitating the use of fluorescent lighting in situations where mains current is not available, the new entirely self-contained fluorescent light units announced by The Plessey Co. Ltd., of Ilford, Essex, have the additional advantages of suitability for use in confined spaces and the fact that they provide a greater light output than tungsten lamps for a similar current consumption.



In these units, which are both compact and portable, the d.c. battery supply is converted to a.c. by a special vibrator working at a frequency of 200 cps and transformed to provide the suitable voltage and regulation to feed the lamp filaments and discharge currents. Instantaneous starting is achieved by straightforward switching of the 24-V, 0·75-A supply, thereby dispensing with the use of supplementary push-buttons or delay switching. As each unit is self-contained, increased dependability and better regulation is afforded, compared with a system employing one power unit for supplying a number of lamps. Specified for use in conjunction with each unit is a 14-mm diameter, 8-W, 12-in. fluorescent tube. Units for operation on a 6- and 12-V d.c. supply are already under development, and it is anticipated that 15- and 20-W units will be available shortly.

Photograph by courtesy of Turner and Brown Ltd.

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NEWS OF THE MONTH

PERSONAL

Mr. A. J. C. MacLeod, A.M.I.E.E., has been appointed Export Manager of the Lancashire Dynamo Group. Since 1951 he has been Export Manager of L.D.C., having joined the company in 1949. He served his apprenticeship with Met.Vic. and remained with them until 1945, subsequently joining E.C.C. **Mr. Peter H. Jackson, M.C.,** has been appointed an Assistant Sales Manager with the Lancashire Dynamo Group.

Mr. D. Craig has been appointed melting shops superintendent of Steel, Peech and Tozer, a branch of The United Steel Companies, Limited S heffield 10, in succession to **Mr. J T. Brookes,** who has retired after 50 years' service.

Mr. F. Buckland has been appointed secretary and office manager of United Coke and Chemicals Company, Limited, and of the Ore Mining Branch of The United Steel Companies, Limited, Sheffield 10. He succeeds **Mr. S. Bacon,** who retired at the end of June after 49 years' service.

Mr. Vincent Watkins has been appointed a Director of Steel, Peech and Tozer, a branch of The United Steel Companies, Limited, Sheffield. Mr. Watkins joined the company in 1943 as Mechanical Maintenance Superintendent, becoming Maintenance Manager in 1948. He has been Chief Engineer since 1953.

Mr. F. Guylee has retired as Managing Director of Frank Guylee & Son Ltd., Sheffield 8, but he retains his interest in the Company as Chairman. His son, **Mr. A. N. Guylee,** has been appointed Managing Director with effect from 1st July, 1957.

Mr. M. F. Lloyd was appointed to the board of Marsh Brothers & Co. Ltd., Sheffield 1, in place of his father, **Mr. Hedley Lloyd,** who died recently in Portugal whilst on a business visit.

F. Perkins Ltd., Peterborough, announces that **Mr. A. J. Dillingham** has resigned from the board on reaching the age of 75.

Mr. P. W. Howard, Managing Director of the British Tyre and Rubber Co. Ltd., London S.W.1, and Chairman of the Research Association of British Rubber Manufacturers, has been elected President of the Association in succession to **Lord Baillieu,** Chairman of the Dunlop Rubber Co. Ltd. **Mr. D. B. Collett,** Dunlop director, succeeds Mr. Howard as the Association's Chairman.

British Insulated Callender's Cables Limited, London W.C.1, announces the appointments of three Branch Managers of Sales Offices in Lancashire. As a result of these appointments, **Mr. C. R. Bryant** is now Manager of the B.I.C.C. Manchester Office, **Mr. F. L. Johnson** is Manager of the Blackburn Office and **Mr. T. Noblett** is Manager of the Preston Office.

Industrial Fan & Heater Co. Ltd., Birmingham 11, announce the appointment for the South Wales area of **Mr. W. H. Dudley** who has moved to the Swansea Office, 256 Oxford Street, as Manager.

George Ellison Limited, Birmingham 22B, announce the appointment of **Mr. H. V. Stanton, B.Sc.,** as Sales Engineer for "Ellison" Switchgear, motor control gear and hydraulic valves in the Surrey, Sussex and Kent areas. With the appointment of Mr. Stanton, re-arrangements have been made in the South-east Area Sales and Consultative service for George Ellison Limited and the areas covered by the other sales engineers have been re-allocated as follows: **Mr. J. Russell-Smith**—Essex, Norfolk, Suffolk, Hunts, Cambs, and Isle of Ely. **Mr. R. J. Roy**—Middlesex, Oxford, Bucks, Berks, Hants, and Isle of Wight. **Mr. F. W. Webb**—Beds and Herts. **Mr. Crowther** will continue to act in a consultative capacity in Sussex, Kent, Hants, and Isle of Wight but will eventually concentrate on Inner London areas, which are also shared between the other sales engineers mentioned above. The management of the London Office of George Ellison Limited at Connaught Place, W.2., will continue to be the responsibility of **Mr. J. R. T. White,** the London Area Branch Manager.

British Insulated Callender's Cables Limited, London W.C.1, announce the appointment of **Mr. N. Pickles** to be Manager of their Lincoln Branch Office.

Mr. F. Clarke, a Director of Airspeed Precision (London) Ltd., London, W.1, has recently joined the board of Saben Hart & Partners Limited, London, W.1. At the same time Mr. F. Clarke has joined the board of Quicktho (1928) Limited who are part of the Metropole Industries Group. The main intention is to co-ordinate the Nuclear Power and Aeronautical developments now in hand.

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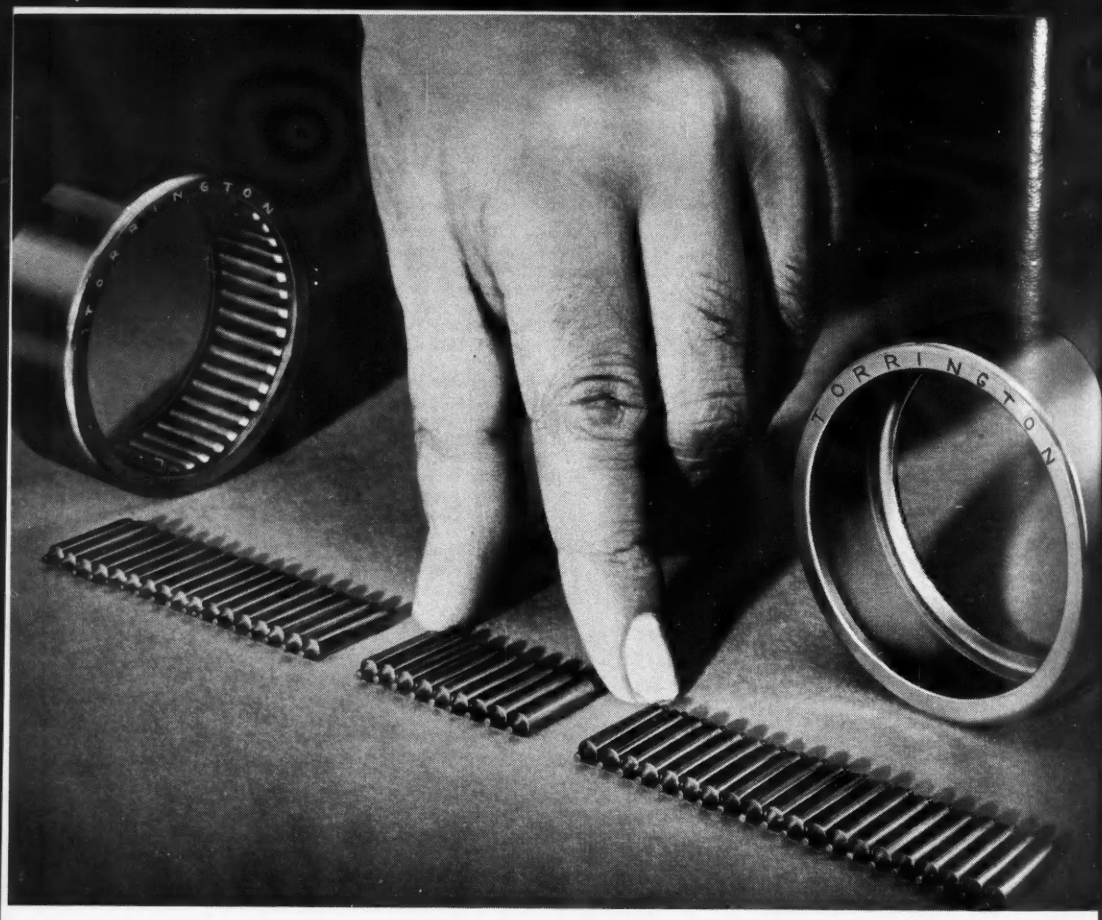

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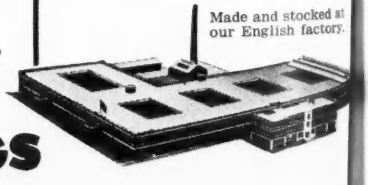

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B/57/D

BUSINESS NEWS

A manufacturing and selling agency for hoists only has been granted in Spain by **Martonair Limited,** Parkshot, Richmond, Surrey. The new agents are **Industrial Alonso,** Apartado 336, Gijon, Spain. Martonair Limited has also opened an office in Scotland at 28 Houston Street, Glasgow, C.3.

Due to continued expansion, **Honeywell-Brown Ltd.** have recently opened a new Branch Office at 5–7 New York Road, Leeds 2. The new office will handle all inquiries concerning industrial instrumentation, heating and air conditioning controls, and precision switches.

As part of an internal re-organization within the group, the manufacturing activities in the past carried on by Albright & Wilson Limited have been transferred to a wholly-owned subsidiary company, **Albright & Wilson (Mfg.) Limited.** All contracts made between suppliers and Albright & Wilson Limited and all orders placed by Albright & Wilson Limited have been taken over by Albright & Wilson (Mfg.) Limited. There will be no change in the addresses of the offices and works from which the manufacturing activities are carried on but all communications should now be addressed to Albright & Wilson (Mfg.) Limited. The head office of this company will be at Oldbury, near Birmingham, which will also remain the head office of Albright & Wilson Limited.

As a result of arrangements finalized by Mr. John E. Bolton, Chairman and Managing Director of **The Solartron Electronic Group Ltd.,** Thames Ditton, Surrey, during his recent visit to the United States, Solartron will manufacture under licence in Britain, the Rheem F.151 Gunnery Trainer. The agreement is with the **Electronics Division** of the large **Rheem Manufacturing Company** of New York, whose many factories are spread out over the United States and several continents.

Due to the expansion of business in the Manchester area and to the increase in engineering staff to deal adequately with customers, **Brush Electrical Engineering Co. Ltd.,** of Loughborough, have built a new block of offices in Chorlton-cum-Hardy and have vacated their office suite in Deansgate, Manchester. The new building includes an extensive drawing office. The address is :— 50 Manchester Road, Chorlton-cum-Hardy, Manchester 21. Telephone 5371/2/3/4.

The Engineering Centre, Birmingham, is again exhibiting at the **Vienna Fair,** 8th to 15th September. The Centre's stand will be in a main position adjacent to the official Board of Trade display in the British Pavilion. The Board of Trade, in conjunction with the British Embassy in Vienna, have again arranged that the Centre should handle all enquiries received on the official stand for engineering products. The Centre will operate an Information Bureau to distribute literature and answer inquiries and it will also display a limited number of British engineering products. Further information can be obtained from the Manager, Engineering Centre, 2 Stephenson Place, Birmingham.

Lancashire Dynamo Holdings Ltd. announce the establishment of a company to be known as **Lancashire Dynamo Group Sales Limited.** This Company, with Headquarters at St. Stephen's House, Westminster, London S.W.1, takes over the sales organization in Great Britain, previously operated by the various Companies in the Lancashire Dynamo Group. It will also co-ordinate the Group's export sales activities. Mr. Stanley F. Steward, C.B.E., is Chairman of the new Company and the other members of the board are Mr. F. H. Schroeder and Mr. H. G. Carter.

INDUSTRIAL PRODUCTS

Two new publications SG/338 and SG/339, entitled respectively "An outline of electrical distribution systems" and "Protective devices applied to electrical switchgear", have been issued by **The English Electric Co. Ltd.,** Stafford. A third publication dealing with industrial distribution substations will be issued in due course to complete this series which are being published to summarize the factors involved in designing a new, or extending an existing, electrical distribution system. Publication SG/338 describes the general problems which usually decide the type of scheme to be used and then gives a number of typical systems which can be used as a basis for almost every individual requirement. Publication SG/339 is a review of the more general types of electrical protective schemes for systems up to 11 kV 250 MVA, and it gives general recommendations for the protection of such items of equipment as transformers, motors and feeders.

A booklet has recently been issued by the **Metal and Pipeline Endurance Ltd.,** London S.W.1, detailing the comprehensive welding inspection and instruction service that they offer to industry.

A new leaflet is now available from **Hot Pressed Products,** Tipton, Staffs., detailing their range of cylinder and boiler fittings. As a member of the SANBRA group of companies H.P.P. also manufacture hot brass pressings, machined pressings and assemblies.

The type 616 plug-in starter, recently developed by **Brookhirst Switchgear Ltd.,** Chester, is a novel design eminently suitable for use in applications where continuous running is essential. The complete interior may be removed and a replacement fitted within half a minute. Designed for use with three-phase squirrel-cage motors up to 7½ hp 550 V 25/60 cycles, the contactor incorporates a triple-pole "block" type model conforming to BS587/1940 and BS775/1956. It has quick-release, double-break, sintered alloy moving contacts and provides inherent under voltage protection. Thermal or solenoid type overload relays are available. With the thermal type relay single phase protection is included.

Burton, Griffiths & Co. Ltd., Birmingham 33, announce that to meet a special application a neutral position snap-lock switch has been designed and put into regular production. Supplies, having the usual optional side or backplate mounting, will shortly be available. Externally the appearance is similar to the now very popular standard normally open-normally closed 16D-1200 snap-lock switch, and dimensionally, it is the same. A movement of 6 degrees to either side will operate the snap action and close the circuit on that particular side. The lever is returned to the centre position by spring pressure, with the circuit being broken after 5 degrees of return movement.

The Sheffield Twist Drill & Steel Co. Ltd., Sheffield 10, announce the publication of a new edition of the Dormer Information Handbook. This issue has been increased to 80 pages and among the new features includes Drills designed for special types of work ; Modifications to standard drills for special applications ; Recommendations for drilling special materials (such as titanium and thermoplastics, etc.); Nomenclature of centre drills. The basic matter of decimal equivalents, speeds and feeds, tapping drill sizes, hints on drilling, point sharpening, etc., is included and, in some cases, is enlarged upon. Copies are available from the Company.

A range of star-delta starters supplied as complete units, either panel mounted or in a separate compact enclosure, are now available from **Square D Limited,** of London, E.C.1.

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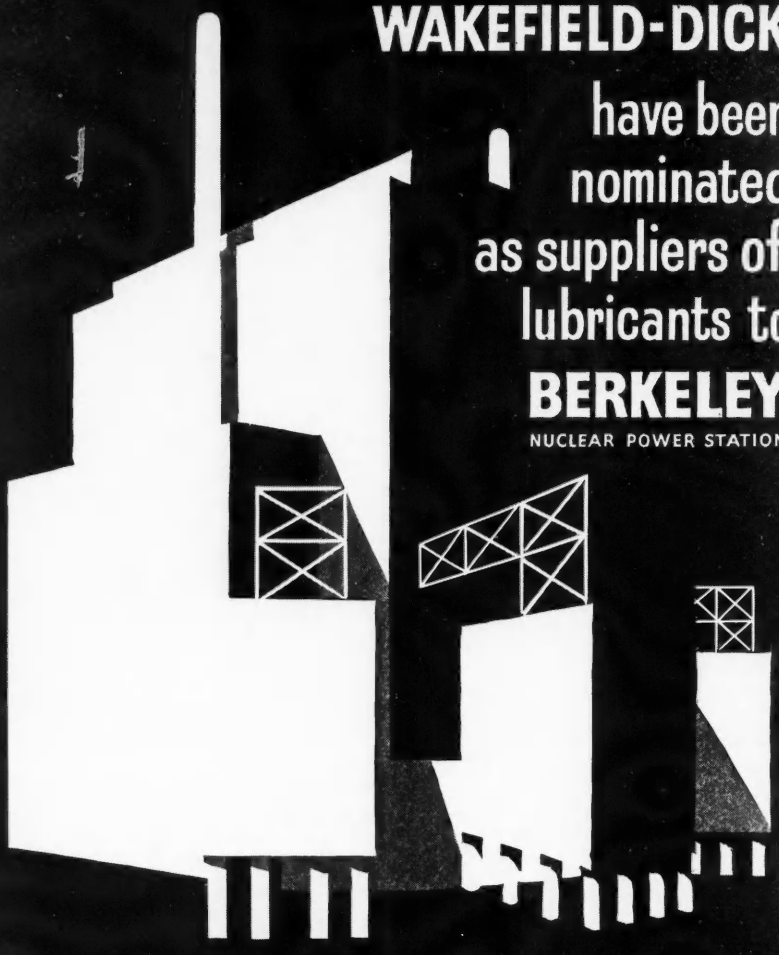

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A recent addition to the well-known Megger range of instruments manufactured by **Evershed & Vignoles Limited,** London W.4, is the 3-voltage insulation tester series 2. This new instrument offers distinct advantages in application where different test voltages are required, all voltages being derived from a single instrument. It is available in two patterns, one pattern having testing pressures of 1,000, 500 and 250 V with an insulation range of 0–200 Megohms whilst the second pattern has testing pressures of 500, 250 and 100 V, with an insulation range of 0–100 Megohms. Both patterns incorporate a switch for the selection of the required pressure. A special feature of this instrument is that the scale range remains the same for each of the three testing pressures selected.

The 74163-A transistor test set, manufactured by **Standard Telephones & Cables Ltd.,** London W.C.2, is a small portable set for measuring the current gain of transistors of the p-n-p type in the common emitter configuration. It will measure gains of 10 to 100, and in some cases gains of less than 10 may be measured, depending on the characteristics of the transistor. The set is completely self-contained in a light alloy box with dimensions approximately $10 \times 7 \times 4\frac{1}{2}$ in. It operates from four 1·5 V dry cells (U2 or equivalent) which are housed in the box.

The advent of the transistor with its low operating potentials has necessitated reductions being made in the physical size of paper capacitors, without, as far as practicable, impairing their electrical performance. To meet this need **The Plessey Company Limited,** Ilford, have recently introduced the " Plesmin " range of paper capacitors. The small size and high standard of performance has been achieved by entirely new methods and processes which have been covered by Patent Applications. Physical sizes are considerably smaller than those made entirely by orthodox methods, the smallest capacitor of the new range measuring only $\frac{3}{8}$ in. long and $\frac{1}{8}$ in. in diameter and the largest $1\frac{1}{4}$ in. long and $^{19}/_{32}$ in. diameter. The range extends from 0·001 μF up to 1·0 μF, with a normal tolerance of ± 20% for 0·01 μF and above, but below this the normal tolerance is ± 25%. Voltages normally covered by " Plesmin " capacitors are 12, 25, 50 and 100 V but working voltages up to 150 V D.C. are also obtainable if ordered specially. An insulation resistance of 1,000 Ohm-Farad minimum at 20°C at the rated D.C. working voltage can be obtained.

Richardsons, Westgarth & Company Limited, Wallsend-on-Tyne, have developed an entirely new type of distilling plant producing pure water from sea water. The plant design is based on an exhaustive series of tests conducted under industrial operating conditions on large size test rigs, using sea water. Operating methods have been developed permitting the plant to be run continuously without being opened for cleaning, and without loss of output due to scaling. Designs for outputs up to 1,000,000 gallons per day (4,500 tons/day) in one unit are available. An order recently received for a unit of this type is for installation in a refinery in Ecuador. Considerable further business is expected in this field, particularly for export, in view of the growing demand for fresh water in a number of arid territories.

A range of new relief valves, designed specifically for handling liquids, is being introduced by **Megator Pumps & Compressors Ltd.,** London, W.1. The design is claimed to be an advance on any other liquid relief valve on the market. The valves, which are made of high quality bronze to BSS 1400-LG3, were originally developed for use with the well-known Megator pumps, to protect the installation against excessive discharge pressure or faulty operation, but they are now available also to industry generally.

A breast battery lighting set, which has been certified by the Ministry of Labour and National Service as intrinsically safe for use in inflammable atmospheres, is now available from **The General Electric Co. Ltd., London, W.C.2.** It was developed in collaboration with a large petroleum company and although designed primarily for use in the oil industry where operations with explosion hazards, such as aircraft refuelling, plant inspection and maintenance, have to be carried out at night, the lighting set has a wide application to industry in general, even where there are no special safety requirements.

A major cause of atmospheric pollution is the discharge to atmosphere of noxious fumes from industrial processes. This problem has been dealt with for many years, in the U.S.A., by catalytic combustion, a low temperature oxidation process by which objectionable fumes are converted to odour free gases. This process, to be manufactured and marketed in the United Kingdom by the Chemical Engineering Division of **W. C. Holmes & Co. Ltd.,** of Huddersfield, is to be known as the Holmes Catco process. The plant is extremely compact and can be connected to existing equipment. Running costs are low, and in processes where the heat in the oxidised gases can be utilized, the plant becomes a power producing unit. Being fully automatic the plant requires a minimum of attention. Maintenance is required, for the fan drawing fumes through the process, and for inspection and removal of the catalyst element for reactivation. The usual life of an element before reactivation is necessary varies from $1\frac{1}{2}$ years to 3 years continuous running, depending on the nature of the application. Re-activation of a catalyst element is carried out by W. C. Holmes & Co. Ltd. at a very small cost.

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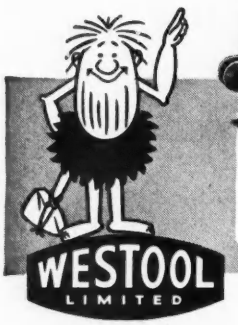

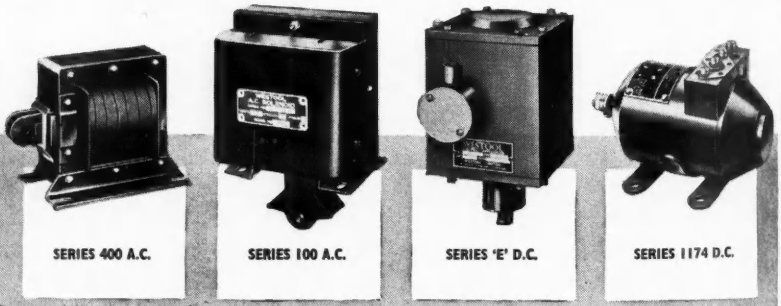

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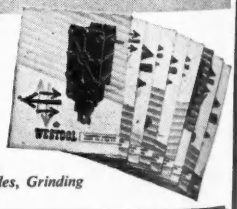

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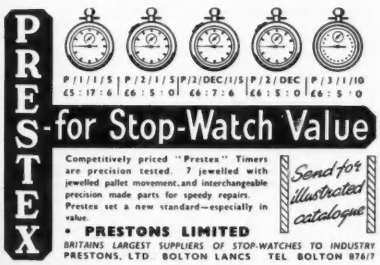
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